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BIG RIVER RESERVOIR PROJECT - PAWCATUCK RIVER AND NARRAGANSETT --ETC(U)

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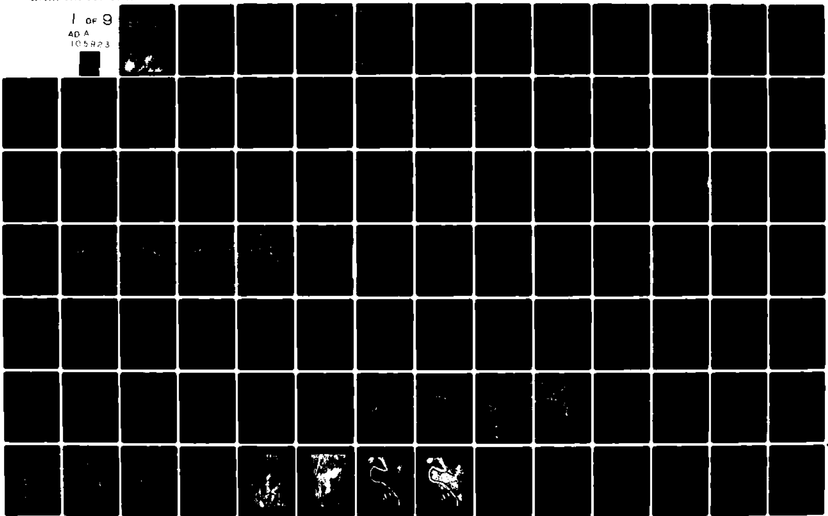

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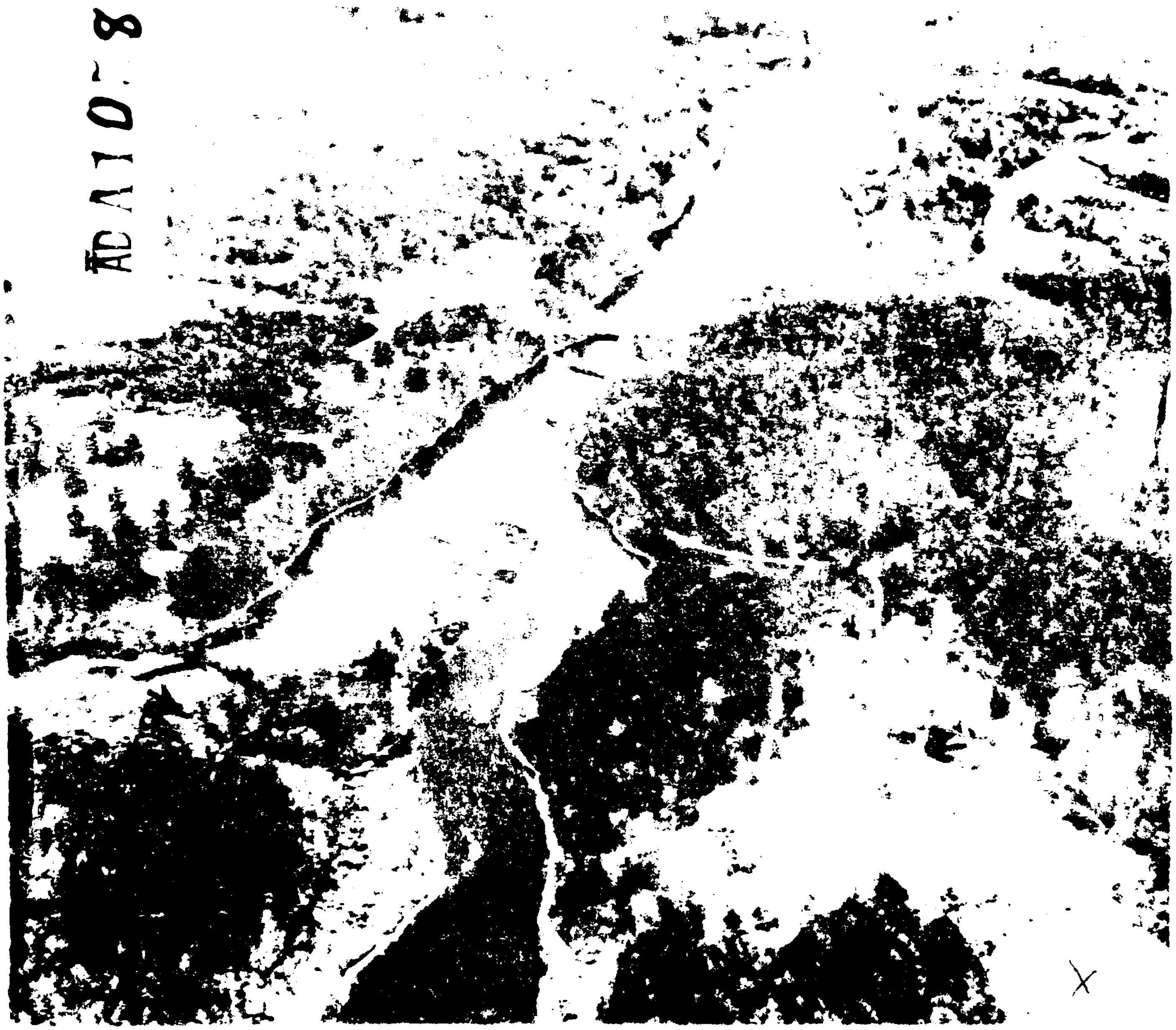
Big River Reservoir Project



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18 SUPPLEMENTARY NOTES

19 KEY WORDS (Continue on reverse side if necessary and identify by block number)

water supply, flood damage, recreation problems, flood prone areas, water resources, flood control, water conservation, groundwater development, surface water development, recreational development, water and related land resources study

20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

Volume IV, Attachment I provides detailed descriptions of the planning process conducted for the Pawtuxet River Basin flood damage reduction study which is summarized in the preceding report volumes.

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NOTICE TO REPORT READERS/REVIEWERS

The Big River Reservoir feasibility study presented in preceding volumes of this report, focused on the development and selection of a plan for solving the flooding, water supply and recreation problems of the study area (including the Pawtuxet River Basin).

Information contained in this Attachment I presents documentation of detailed studies undertaken to formulate plans for flood damage reduction in the Pawtuxet River Basin. These plans, and the recommendations of the study's report were incorporated in the plan formulation process of the Big River Reservoir Study and were utilized in the development of water resources management plans.

Attachment I, therefore, provides the reader with detailed descriptions of the planning process conducted for the Pawtuxet River Basin flood damage reduction study which is summarized in the preceding report volumes.

Pawcatuck River and Narragansett Bay Drainage Basins

Water and Related Land Resources Study

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BIG RIVER RESERVOIR PROJECT

INDEX OF VOLUMES

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PAWCATUCK RIVER AND
NARRAGANSETT BAY DRAINAGE BASINS

INTERIM REPORT
PAWTUXET RIVER WATERSHED
RHODE ISLAND

Main Report

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

CHAPTER I

INTRODUCTION

PLATES

INTRODUCTION

The purpose of this study is to investigate the flooding and associated water resource problems in the Pawtuxet River Basin and to develop a plan, acceptable to the local interests, that would solve these problems. Various flood control alternatives responsive to the needs of the basin are presented in this report.

STUDY AUTHORITY

This report is submitted in partial compliance with seven Congressional resolutions, combined under one resolution adopted by the Committee on Public Works of the United States Senate. These resolutions submitted after the March 1968 flood, authorized the Pawcatuck River and Narragansett Bay Drainage Basins (PNB) Study, which includes the Pawtuxet River Basin.

SCOPE OF THE STUDY

This report presents the results of a study of the flooding and water resources problems in the Pawtuxet River Basin, one of five major watershedzs in the Pawcatuck River and Narragansett Bay Drainage Basins (PNB) Study. It makes a determination of the advisability of making improvements in the interest of flood control and allied purposes. A map showing the relationship of the Pawtuxet River to the entire PNB study area follows as Plate I-1. All reasonable alternative plans to solve the area's water resource problems were considered. The selection of the recommended plan was made after considering all factors, including those expressed by concerned agencies and local interests. The studies were made in the depth and detail needed to permit plan selection and to determine its feasibility.

The remainder of the river basins included in the authorizing resolutions will be considered in separate feasibility studies. See Appendix for listing of reports. A separate ongoing interim report for Big River Reservoir in the headwaters of the South Branch Pawtuxet River is currently being prepared by this office. That report is investigating the socio-economic effects as well as deriving detailed costs for the multi-use reservoir. Several preliminary reports have derived various cost estimates for a water supply reservoir and a water supply-flood control reservoir. These prior estimates considered varying subsurface conditions as a part of the ongoing study. A detailed foundations and materials analysis has been undertaken. This report is attached to the detailed Big River Reservoir report.

STUDY PARTICIPANTS AND COORDINATION

The New England Division, Corps of Engineers, had the principal responsibility for conducting and coordinating the study and the plan formulation, consolidating information from the studies by other agencies, and preparing this report. Other participants were contacted during the progress of the study and their views incorporated, included the following:

Federal Agencies

U.S. Fish and Wildlife Service
U.S. Environmental Protection Agency
New England River Basins Commission

State Agencies

Rhode Island Water Resources Board
Statewide Planning Program
Department of Public Health
Department of Environmental Management
Historical Preservation Commission

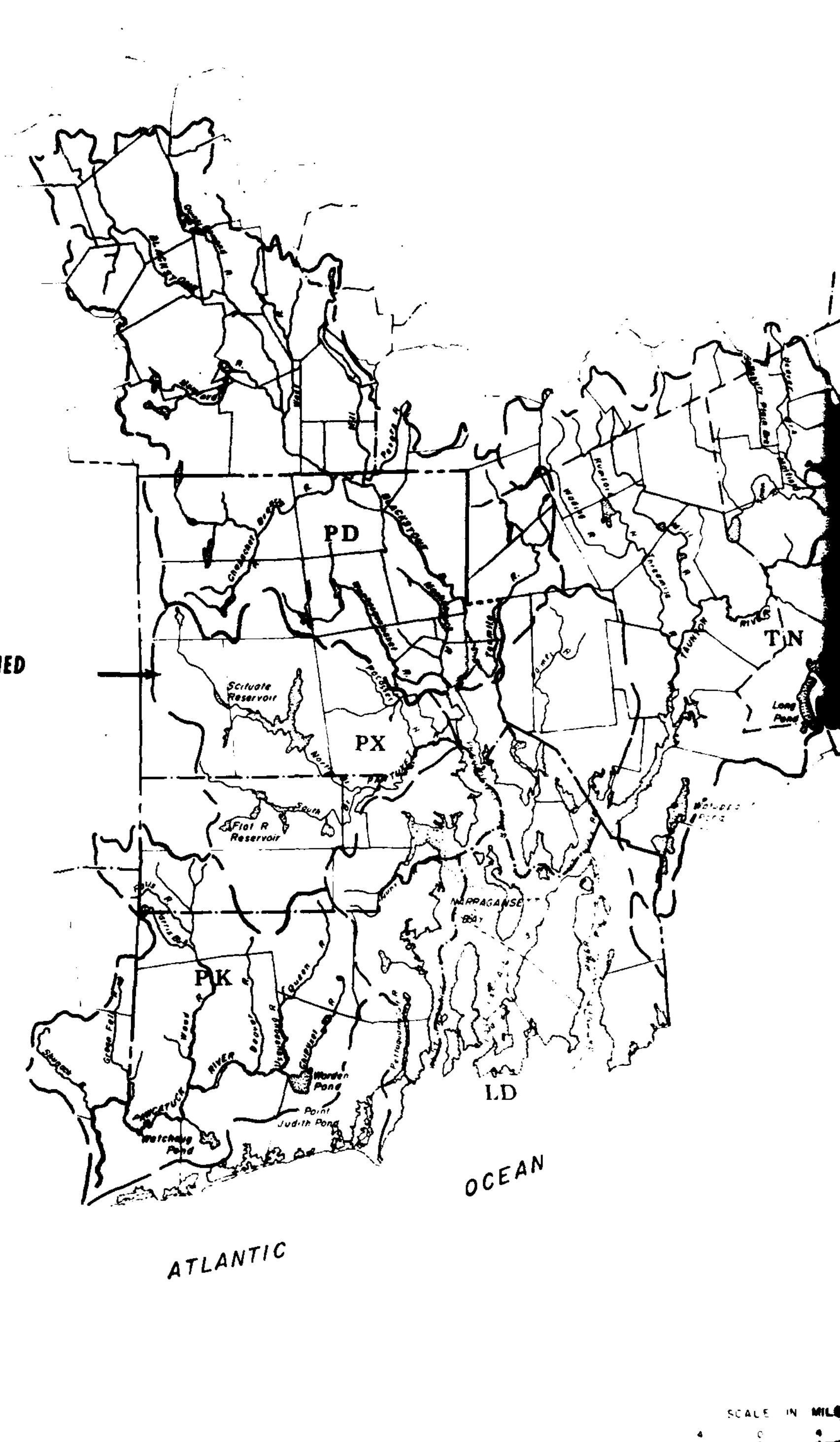
Local Agencies/Organizations

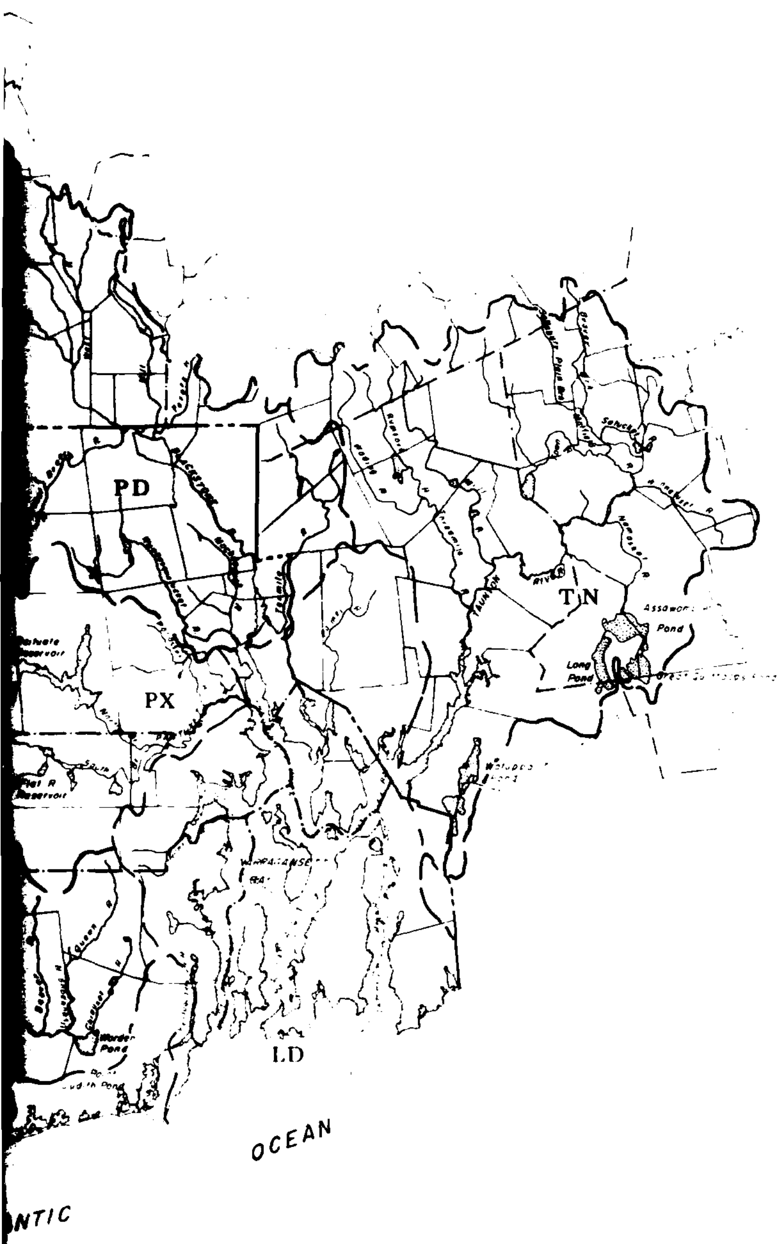
City of Warwick
City of Cranston
Town of West Warwick

Four initial public meetings were held in May 1969 for the PNB study. These meetings were held in Taunton and Uxbridge, Massachusetts and Providence and Kingston, Rhode Island. The purpose of these meetings was to afford local interests the opportunity to express their needs and desires, to exchange information concerning the study, and to comment on some of the possible plans that could be considered. Subsequent to those meetings, numerous informal meetings were held with State and municipal interests and concerned citizens.

Two plan formulation public meetings were held on 6 and 8 May 1975 at Warwick and Cranston, Rhode Island, respectively. The purpose of these meetings was to present all of the alternative plans developed during the investigation and to incorporate public desires in plan formulation and choice of the most desirable alternative. Information booklets and plans were distributed prior to these public meetings to all concerned Federal, State and municipal interests, news media, and approximatley 325 organizations and individuals. At these meetings, the people supported the Natick Diversion tunnel, the Norwood Local Protection, the Warwick Avenue Local Protection and a

PAWTUXET RIVER WATERSHED





LEGEND

	COMMUNITY BOUNDARY
	COUNTY BOUNDARY
	STATE LINE
PD	PROVIDENCE RIVER GROUP
PX	PAWTUXET RIVER BASIN
TN	TAUNTON RIVER BASIN
PK	PAWCATUCK RIVER BASIN
LD	LOCAL DRAINAGE

SCALE IN MILES

4 0 4 8

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

PNB STUDY AREA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE I-1

future action program consisting of incremental flood control storage at Big River Reservoir. They requested that additional environmental studies on the diversion tunnel be conducted along with a nonstructural plan for the heavy damage areas.

The requested work items evolving from the public participation program were completed. A subsequent public meeting was held in Warwick on 14 October 1976 presenting the results of the study findings. Copies of the report and the draft Environmental Impact Statement were distributed to the public prior to the meeting. The recommended plan consisted of the same measures previously presented. This plan was now found to be unacceptable to the public. Although the plan was economically feasible, opposition from out-of-basin residents cited high construction costs ($60,000,000 project cost) and fear of environmental harm to Apponaug Cove and Greenwich Bay.

Subsequent meetings held between October 1976 and May 1977 to determine the future course of action resulted in additional plans being offered for conservation. They were presented at another late stage public meeting held on 19 May 1977. Local flood management measures and study findings were discussed with Warwick and State officials on 3 March 1979, Warwick residents on 8 March 1979, and Cranston officials on 4 May 1979.

STUDIES OF OTHERS

Numerous reports have been prepared focusing attention on the Pawtuxet watershed. Some of the more pertinent are listed below:

Early Rhode Island Water Supply Reports, 1928-1936

Flood Control Survey Report of 1939

The New England-New York Inter-Agency Committee Report, March, 1955

Navigation Survey Report, June 1961

Narragansett Bay Area Hurricane Survey Reports, August, 1957

Rhode Island Water Supply Reports, June, 1967

Northeastern United States Water Supply Study Feasibility Report, November, 1969

Flood Control Reconnaissance Report, December, 1971

North Atlantic Regional Water Resources Study Report, June, 1972

Brown University Water Quality Report, August, 1972

Cranston Flood Hazard Analysis Report, September, 1973

Flood Control Project Environmental Reports, February, 1975

Southeastrn New England Study, March, 1976

Mathematical Model Analyses, March, 1976

EPA Water Quality Study, September 1975

PNB Water Supply, Study, January 1979

U.S.G.S. Water Resources Investigations

Rhode Island Statewide Planning Program, Public Water Supply Plan, September 1969

Providence Water Supply Board Report, 1968

Bristol County Water Supply Report, May 1979

Flood Insurance Studies under the authority of the National Flood Insurance Act of 1968 have been completed for Coventry, Cranston, Providence, Exeter, Johnston, Warwick, West Warwick and West Greenwich. These communities are now on the Regular Program.

CHAPTER [illegible]

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PROBLEM IDENTIFICATION

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National Objectives

These objectives are directed towards National, State, and local water and related land resource management needs specific to a given study area that can be addressed to enhance multiple objectives of National Economic Development (NED) and Environmental Quality (EQ).

Components of the NED objective for the Pawtuxet River Basin are:

1. Reduce flood damages along the mainstem and tributaries of the Pawtuxet River.
2. Opportunities for additional water supply to the State of Rhode Island.
3. Improve the economy of the underemployed labor force.

Components of the EQ objective for this study area are:

1. Prevent further water quality degradation of the Pawtuxet River and its tributaries.
2. Create recreational areas to satisfy local demand for noncontact uses.
3. Develop a management plan precluding unwise use of the flood plain.

Existing Conditions

The Pawtuxet River Basin located in west-central Rhode Island consists of two principal branches which merge to form a 10.9-mile long main stem. The North Branch rises in the hilly uplands of Foster and Glocester near the Connecticut border and flows in a generally southeasterly direction through Providence and Kent Counties toward Narragansett Bay. The other branch, the South, originates in the slightly lower uplands of Coventry, West Greenwich and Exeter in Kent County, and flows easterly through West Warwick. At this town it merges with the North Branch to form the mainstem of the Pawtuxet River. The river flows in a northeasterly direction, through West Warwick, Warwick and Cranston before it discharges into Narragansett Bay via Pawtuxet Cove. Flows from several smaller tributaries enter the mainstem.

The watershed is triangular in shape, having a maximum length of 18 miles running west to east and 23 miles width from north to south. The drainage area at its mouth in Pawtuxet Cove is 230 square miles. The Woonasquatucket and Blackstone River Basins bound the watershed on the north, the Thames Basin on the west, the Pawcatuck on the southwest and Narragansett Bay local drainage on the southeast. A basin map is shown on Plate II-1.

The Pawtuxet Basin has an average temperature of 50°F and a range from -15°F up to 100°F. The annual precipitation averages between 40 and 48 inches, with an average annual snowfall of about 38 inches. Table II-1 shows monthly and annual precipitations at Providence, including mean monthly snowfall. The area escapes the severity of cold and the greater depths of snowfall experienced in the higher elevations of interior New England due to the moderating influence of Narragausett Bay. The climate is variable, with frequent but generally short periods of heavy precipitation caused by four general types of storms:

Continental storms originating over the central or western United States, move east with the prevailing westerlies. They may be rapidly moving cyclones, or stationary frontal storms of varying intensity which follow one another at more or less regular intervals throughout the year.

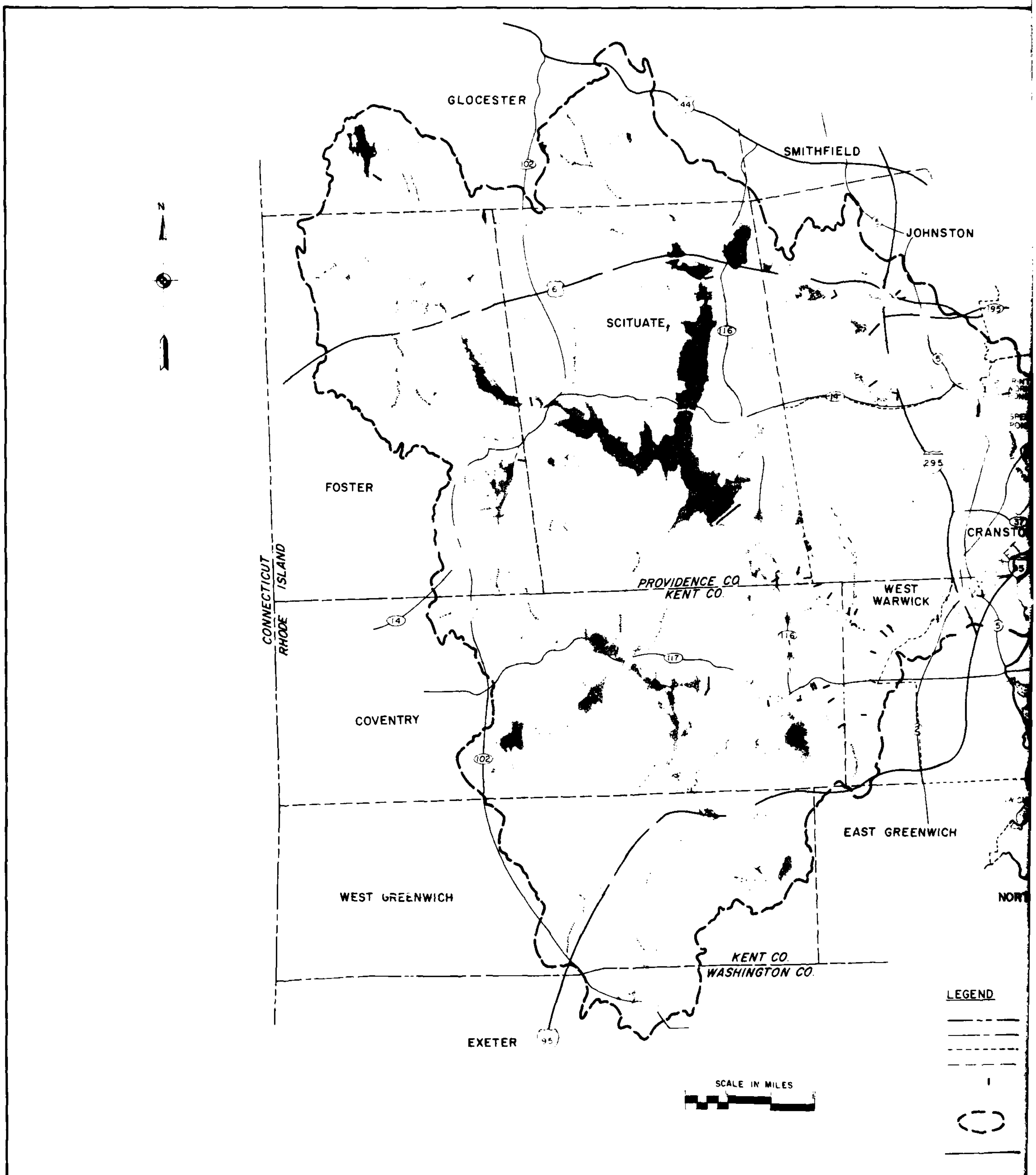
Extratropical coastal storms move northeasterly up the coast of the United States, generally in the autumn, winter, and spring months. They may develop into "northeasters" which can stall off the New England coast for several days.

Tropical coastal storms which may have impact on New England between late spring and early autumn, usually move northward along the Eastern Seaboard and then recurve northeasterly, passing to the south and east of New England. Hurricanes, the most severe of the tropical storms, may be drawn over the New England area by continental cyclonic disturbances or deflected by "blocking highs" east of New England. The lower reaches of the Pawtuxet River are susceptible to the tidal flooding that usually accompanies tropical hurricanes.

Thunderstorms produced by local convective activity during warm, humid days in the summer, or associated with a frontal system moving across the watershed, can cause local flooding on tributary streams or more general flooding when abnormal streamflow or saturated surface conditions exist.

TOPOGRAPHY

The Pawtuxet River Basin is located entirely within the New England Physiographic Province, which is a subdivision of the Appalachian Highlands that extend from Newfoundland to Alabama. The eastern two-thirds



GLOCESTER
SMITHFIELD
JOHNSTON
SCITUATE
FOSTER
CRANSTON
CONNECTICUT
RHODE ISLAND
PROVIDENCE CO.
KENT CO.
WEST WARWICK
COVENTRY
EAST GREENWICH
WEST GREENWICH
KENT CO.
WASHINGTON CO.
EXETER
LEGEND
SCALE IN MILES
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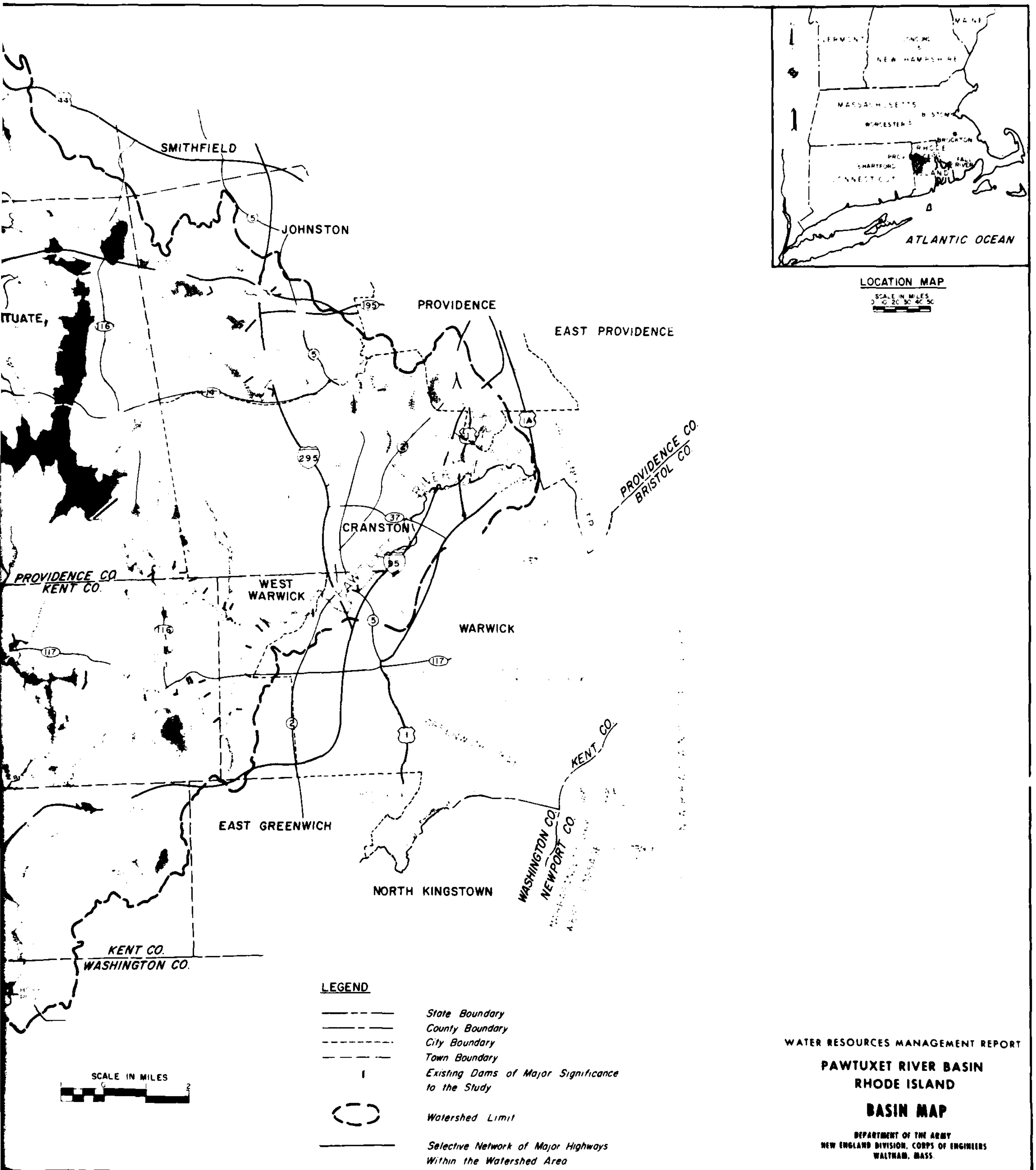
SMITHFIELD
JOHNSTON
PROVIDENCE
EAST PROVIDENCE
ITUATE,
CRANSTON
WEST WARWICK
WARWICK
PROVIDENCE CO.
BRISTOL CO.
PROVIDENCE CO.
KENT CO.
EAST GREENWICH
NORTH KINGSTOWN
KENT CO.
WASHINGTON CO.
NEWPORT CO.
KENT CO.
WASHINGTON CO.
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City Boundary
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Selective Network of Major Highways Within the Watershed Area
SCALE IN MILES
WATER RESOURCES MANAGEMENT REPORT
PAWTUXET RIVER BASIN
RHODE ISLAND
BASIN MAP
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE II-1

TABLE II-1

MONTHLY TEMPERATURE, PRECIPITATION AND SNOWFALL DATA
AT PROVIDENCE, RHODE ISLAND
40 YEARS OF RECORD

Month	TEMPERATURE DEGREES FAHRENHEIT			PRECIPITATION INCHES			SNOWFALL (INCHES)
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	
January	29.3	65	- 9	3.49	7.12	0.50	10.2
February	29.3	65	-15	3.23	[illegible].63	1.31	10.5
March	37.5	86	1	3.67	8.31	1.49	7.8
April	47.5	87	14	3.5[illegible]	7.32	0.72	0.5
May	57.8	94	29	3.10	9.25	0.57	0
June	66.9	97	39	2.91	7.21	0.04	0
July	72.6	99	46	3.05	6.92	[illegible]	0
August	70.8	100	40	3.[illegible]	12.24	[illegible]	0
September	63.8	99	32	3.2[illegible]	9.74	0.77	0
October	54.0	88	21	3.00	11.89	[illegible].16	trace
November	43.4	81	12	3.65	8.50	0.67	1.3
December	32.4	69	-11	3.74	10.75	0.58	7.8
ANNUAL	50.4	100	-15	[illegible]0.32	[illegible]8.5[illegible]	25.44	[illegible]7.50

of the basin lies within the Seaboard Lowland Section where elevations range from sea level near the coast to over 500 feet inland. Moderately hilly topography becomes more rugged proceeding westward and northward. Valleys become narrower and moderately steeper, contributing to extensive development of industrial dams.

The western third of the basin lies within the New England Upland Section, with elevations ranging from 300 to over 700 feet. The irregular topographic surface of the basin is controlled primarily by underlying bedrock rather than by surficial materials. The moderately hilly topography was modified by glacial activity which eroded the hilltops and deposited materials in the valleys, thereby reducing the overall relief of the area.

SURFICIAL GEOLOGY

Glacial deposits occur throughout the basin. They vary from shallow thickness at higher elevations on the sides and tops of hills, to considerably greater thickness in the valleys and at lower elevations. These deposits are essentially mixtures of sand, silt, gravel, and boulders. Moderately extensive swamps contain soft organic silt and peat.

Ground moraine or till -- an unsorted mixture of particles ranging from clay-size to boulders -- is the principal deposit of the basin. Outwash plains of sand and gravel are prevalent in the eastern and southern parts.

Future planning and development of the basin is subject to the geologic restraints of these topographic conditions. Foundation conditions are generally good. Subsurface drainage is poor to fair. The eastern and southeastern sections are highly developed, due to the relative ease of working with these glacial deposits. Planning must place a strong, controlling emphasis on low permeability soils in the hills, high groundwater levels in the valleys, and significant flood plains in the lower basin.

Engineering factors include bearing capacity, which is generally good in the basin except in swamps, control of surface water in areas of low permeability soils, and monitoring of groundwater levels.

Construction factors include the difficulty of excavation in high density soils where boulders are present and where bedrock is at or near ground surface. Areas of sand and gravel deposits in valleys are generally most desirable for construction projects.

BEDROCK GEOLOGY

The bedrock of the Pawtuxet River Basin includes metamorphic, igneous, and sedimentary types. The central portion of the river basin is extensively granite, sandstone, slate, and conglomerate to the east. Two faults within the basin are not considered major or active.

Planning factors center on the desirability and difficulty of excavation of rock used for construction purposes.

Engineering factors are concerned with utilizing the high compressive strength, slight weathering action, and good to excellent durability characteristics.

Construction factors relate chiefly to the high excavation difficulty encountered on the sides and tops of hills.

SEISMIC ACTIVITY

Most of the basin is classified as an area of minor damage potential. The northern most section may undergo moderate damage. The potential for earthquakes must be evaluated and appropriate factors applied to designs.

MINERAL RESOURCES

There are seven active sand and gravel producers within the basin. Until recent years, anthracite coal was mined intermittently in Cranston.

WATER SUPPLY

Groundwater supplies exist in varying amounts throughout the basin. The western half and the western sections of Cranston and Johnston are served by private wells. The two most promising groundwater reservoirs lie in the southeastern Coventry-northeastern West Greenwich area and in the eastern Cranston-southwestern Providence area. More than three million gallons per day (MGD) are presently withdrawn from the Cranston-Providence aquifer by industrial users. But the high potential for contamination from urban development, plus moderately high iron and chloride concentrations, make it unlikely that public supply wells will be developed here.

In the South Branch drainage area, the Kent County Water Authority obtains nearly 3 MGD from the edges of the Coventry-West Greenwich

aquifer, which is of good chemical quality. Possible future export of groundwater from this system could result in reduced natural discharges into tributary streams and the South Branch. Although injection of treated wastewater has been rejected as uneconomical for aquifer recharge, spray irrigation is considered a future option for aquifer recharge in the South Branch system.

Surface water from the Scituate Reservoir and five upstream reservoirs is supplied to much of the eastern portion of the basin. The Providence Water Supply Board obtains 72 MGD from these sources for the Providence system, as well as for sale to other communities. Projections indicate current supply will be unable to meet demand in 1985-90, and the Rhode Island Water Resources Board has acquired land and has initiated design studies for the proposed Big River Reservoir project, upstream from the southern arm of the Flat River Reservoir. It would have an initial yield of 29 MGD for an expanded Providence system.

WATER QUALITY

Existing water quality classification in the Pawtuxet River Basin are as follows:

Class A -- suitable for domestic water supply: Scituate Reservoir and the Big River;

Class B -- suitable for domestic water supply with appropriate treatment and for swimming: Flat River Reservoir and the upper reaches of the North and South Branches;

Class C -- suitable for fish and wildlife habitat and boating: most of the main stem and the lower reaches of the North and South Branches;

Water quality problems, which are mainly in the lower reaches of the tributary streams and in the entire mainstem, can be attributed to inadequate septic tank systems, urban runoff, sluggish flow conditions caused by numerous dams, frequently inadequate streamflows to assimilate the effluents from existing treatment facilities inundation of sludge drying areas, and leachate from solid waste disposal areas.

There are three municipal wastewater treatment plants along the mainstem of the Pawtuxet River in West Warwick, Warwick and Cranston, plus a State sewage treatment facility at Cranston, in addition to several other industrial treatment plants within the basin. Expansion of these plants and/or a new plant at Coventry is under consideration.

Although all facilities now provide the equivalent of secondary treatment, future growth and plans for expanded sewerage systems will result in additional pollutional loads being placed on the receiving waters of the lower Pawtuxet. Although the overall water quality of the Pawtuxet has improved considerably in recent years, it is not expected that Class B waters can be readily attained in the lower Pawtuxet in the near future. As significant augmentation of existing low streamflows (particularly low during most weekends) appears unlikely in view of increasing water supply demands, it appears that more sophisticated treatment measures will be required at existing treatment plants if higher quality water is deemed necessary.

SOILS AND VEGETATION

The lowlands of the basin consist of well drained, Merrimac, fine sandy loam with narrow bands of poorly drained alluvial soil in the bottom lands along many streams. The low hills are principally well drained, Narragansett fine sandy loam. In the higher uplands, the predominant soil is well drained, Glocester, stony, fine sandy loam, with extensive areas of rough, stony land.

Dairy farming, poultry farming, fruit growing, and truck gardening are the principal agricultural activities of the basin, although a relatively low percentage of the land in the basin is under intensive cultivation or pasturage.

Outside of Providence, forested lands total between [illegible] percent in the eastern communities and 82 percent in the western communities of the basin.

Extensive wetland areas exist in southeastern Coventry, northeastern West Greenwich, and along the Big, Nooseneck, and Carr Rivers that drain into the Flat River Reservoir. There are also numerous smaller wetlands in the Pocasset River and Meshanticut Brook watersheds. The largest of the wetlands is the Mishnock swamp complex.

FISH AND WILDLIFE

Although the basin has an extensive network of streams and ponds with fishing potential, most of these water bodies are not accessible to the public. All but two industrial water supply reservoirs are closed to the public. Only nine streams are stocked with trout. Principal warm-water harvestable fish species include largemouth and smallmouth bass, chain pickerel, brown bullhead, sunfish, and yellow and white perch. Most of the accessible streams and ponds need fishery management as most bodies within the basin carry unbalanced fish populations consisting

principally of small, undesirable species. Existing dams and stream pollution preclude anadromous fisheries or the development of fishways.

OUTDOOR RECREATION

The basin is oriented toward warm weather recreation. All communities have athletic fields and tennis courts, and most lower basin communities have swimming pools. State and municipal salt water beaches are available in Warwick. Public picnic facilities are available in all communities and at State parks in and just outside the basin.

There are five golf courses, three privately operated camping areas, and three boy's camps. Hunting is a popular activity on public and non-posted private lands throughout the basin. Seven trout streams are stocked by the State.

Fresh water boating is limited to a few reservoirs and ponds. There are a few State boat launching ramps. The basin population has ready access to extensive salt water boating facilities nearby. Sportfishing boats may also be chartered.

HUMAN RESOURCES

POPULATION CHARACTERISTICS

The estimated 1970 population of the 230-square mile Pawtuxet River Basin was 180,000, or 782 persons per square mile. In the more densely populated eastern third, population densities range up to 8,182 in Providence. In the three downstream communities -- Warwick, Cranston and West Warwick -- estimated population is 110,400, and population density is about 2,647 persons per square mile. Table II-2 shows community size and population growth. Population projections and community development are summarized under "Future Development" at the end of this section.

In 1970, 7.8 percent of the State's residents were foreign born and 25 precent had foreign or mixed parentage. Roughly one-third of the ethnic backgrounds were Italian or Canadian. British, Irish, Portuguese, Polish and Russians accounted for another third, with all other origins accounting for the remainder. The black population, representing slightly less than 3.3 percent of the State population, is mostly native born, with over half residing within Providence.

COMMUNITY CHARACTERISTICS

The six upper basin communities average about 54.4 square miles in area, with Coventry being the largest with the area of 62.2 square miles. The five lower basin communities average about 22.7 square miles in area with West Warwick being the smallest with an area of 8.[illegible] square miles. Excluding inland water areas and classifying agricultural lands as "undeveloped," only 6.5 percent of the upper basin was developed in 1970 as compared with 54.8 percent of the lower basin. Data concerning median age, education, income, housing and employment are presented in Table II-3, "Community Profiles." Two communities, Smithfield and East Greenwich were excluded from the table as only approximately 25 acres in Smithfield (mostly orchard) and 115 acres in East Greenwich (mostly forest with limited residential development) are located within the basin limits.

Manufacturing is the principal employment in the six lower and middle basin communities (including Coventry), accounting for 30 to 44 percent of the total employment. Education is the principal occupation in the five upper basin communities, averaging about 24 percent of the total employment. Trade is the second largest occupation in all com-munities, followed generally by service skills, government, construction and other skills.

TABLE II-2

COMMUNITY SIZE AND POPULATION GROWTH

Community	Area * (Sq. Mi.)	Percentage Within Basin	1970 Density	1950 Population	1960 Population	1970 Population	1990** Population	2020*** Population	AVERAGE ANNUAL GROWTH 1950-1970 (Percent)	1970-1990 (Percent)	1970-2020 (Percent)
Coventry	62.2	66.10	369	9,869	15,432	22,947	32,100	40,200	4.4	1.7	1.2
Cranston	28.6	99.98	2,509	55,060	66,766	74,287	86,000	107,700	1.5	0.8	0.7
Exeter	58.2	5.66	56	1,870	2,298	3,245	4,800	7,000	2.7	2.1	1.6
Foster	51.4	59.26	51	1,630	2,097	2,626	3,800	5,900	2.4	1.9	1.7
Glocester	55.3	25.09	93	2,682	3,397	5,160	7,200	10,000	3.4	1.7	1.3
Johnston	23.7	77.57	825	12,725	17,160	22,037	31,500	39,400	2.8	1.7	1.1
Providence	18.1	18.33	9,896	248,074	207,498	179,116	187,000	195,000	-1.6	0.2	0.2
Scituate	48.8	100.00	153	3,905	5,210	7,489	9,200	12,400	3.4	1.0	1.0
Warwick	34.9	22.96	2,398	43,028	68,504	83,694	105,900	132,600	3.4	1.2	0.9
West Greenwich	50.6	46.40	36	847	1,169	1,841	3,200	4,800	3.9	2.9	2.0
West Warwick	8.3	62.22	2,930	19,096	21,414	24,323	26,700	33,400	1.3	0.8	0.7

* Land area as compiled by U.S. Bureau of the Census (excludes inland water areas)

** R.I. Statewide Planning Program 1990 Projections

*** OBERS Series E 2020 Projections

TABLE II-3

COMMUNITY PROFILES

Community	Median Age (Years)	Median School Years Completed	Completed High School (Percent)	Family Income (1967 $)	One Family Homes (Percent)	Housing Median Value (1967 $)	Owner Occupied Housing (Percent)	Housing Vintage 1939 - Earlier (Percent)	Principal Employment
Coventry	25.8	11.7	47.3	10,630	82.1	17,900	79.1	29.6	Textiles, trade
Cranston	34.9	12.1	51.7	10,778	64.8	18,600	46.0	48.4	Trade, government
Exeter	26.4	9.1	34.2	9,327	69.6	15,300	67.0	23.4	Government, trade
Foster	29.4	12.2	57.4	9,838	87.5	15,700	78.3	49.5	Government, services
Glocester	29.0	12.0	51.1	10,175	84.5	16,800	80.2	41.4	Government, trade
Johnston	29.6	10.9	38.6	10,259	74.8	18,600	64.3	39.8	Trade, government
Providence	32.1	10.9	40.6	8,430	21.7	16,800	33.2	80.7	Trade, jewelry
Scituate	30.9	12.1	53.0	10,652	86.9	19,700	78.1	37.0	Textiles, government
Warwick	30.1	12.2	55.8	11,006	86.0	17,100	79.2	34.2	Trade, government
West Greenwich	26.5	11.0	N.A.	9,796	50 +	15,900	65.7	N.A.	Government, services
West Warwick	28.9	10.4	37.1	9,485	46.6	17,300	52.4	55.3	Trade, textiles
Rhode Island	31.8	11.5	29.0	9,736	51.6	18,200	57.9	34.8	Clerical, manufacturing

DEVELOPMENT AND ECONOMY

EARLY DEVELOPMENT

Prior to the arrival of European settlers, Rhode Island was inhabited by five Indian tribes of Algonquin stock. The first European settlement was established in 1636 by Roger Williams, who fled the Massachusetts Bay Colony and purchased the northern half of what is now Rhode Island from the Narragansett tribe. Other settlements in the basin followed in Cranston, Warwick, Coventry, and other locations.

During the early years of development, the scattered villages were principally agricultural communities. Early industries included gristmills and sawmills at a few waterpower sites, and an iron foundry in Scituate. Limited mining of bog iron ore, soapstone, and granite took place and a small fishing industry developed. The seaport of Providence served the waterborne commerce needs of the basin, as it does today.

In the early 1800's, numerous waterpower sites were developed for the manufacturing of textiles. A jewelry and silverware industry developed, and many industrial sites were established along the North and South Branches, and the Pocasset River. Subsequently, metal fabricating industries developed.

LATER DEVELOPMENT AND URBANIZATION

The Industrial Revolution saw many major groups of mills established along the mainstem, the North and South Branches, and the Pocasset River. Each group became an independent community. Each set of mills was worked by a distinct ethnic group, and British workers were first displaced by Irish, then French-Canadian, Polish, Italian, and most recently Portuguese. These strong, local communities precluded the growth of "downtown" central business districts, except in Providence.

From the Civil War through World War I, the area continued to prosper and its industrial base grew. During the 1920's, however, textile mills began to move south and the lower basin communities began to decline. There was relatively little growth or migration during the depression of the 1930's.

The turning point in the economy came in the early 1940's, when mills were converted to war work and new industries developed, such as electronics, precision instruments, and plastic and synthetic fibers. Many new jobs were created at naval installations at North Kingstown and Newport. And the extension of the public transit system from Providence into the lower basin communities, along with the growth of automobile transportation created new suburban development.

Between 1950 and 1970, Providence lost significant population, while all other lower basin communities grew, some very rapidly. Many new residents were attracted by the desirability of suburban living close to Narragansett Bay. Migration was assisted by the availability of a good highway system. Two massive shopping centers were built in the Pawtuxet flood plain, as well as a number of manufacturing and service industries.

Despite this growth, Rhode Island as a whole has generally experienced higher unemployment rates than the rest of the nation. Since World War II, there has been only one boom period (1965-70), but four major recessions. During the present recessionary period, Rhode Island's unemployment rate has remained roughly twice the national average.

Rhode Island has been a marginal producer, quick to feel the effects of economic downturn and slow to reap the rewards of prosperity. Rhode Island has one of the lowest educational attainment levels in the nation, thus restricting many residents to low paying jobs. Lack of public services has also restricted the growth of industry.

Textiles, jewelery, and silverware continue to be major industries, with Providence still providing the preponderance of jobs for basin residences. In the other basin communities, trade, diversified manufacturing, government, and service industries represent the major employment classification. The loss of 20,000 military personnel and 10,000 civilian jobs through the phase-out of the state's two major naval installations has created severe economic hardship, although this should be partially offset by the utilization of one former naval installation at North Kingstown for the construction of nuclear submarines.

Urban sprawl and commercial strip development have characterized much of the growth radiating out from the earlier mill villages. New industrial growth has tended to cluster along service roads or railroads, and more recently in industrial parks. Table II-4 shows Land Use in 11 basin communities.

TRANSPORTATION FACILITIES

Providence is a key wholesale distribution center in the heart of the New England market. The basin is well served by all types of transportation.

Major highways include I-95 connecting Boston, Providence, and New York; I-295, the southwestern end of the outer belt highway around Providence; two high-speed connectors, one to the State airport; U.S. 1; and Rhode Island Routes 2 and 4. U.S. 6 connects Providence with Hartford, and

TABLE II-4

LAND USE

Community	Land Area*	Inland Water*	Total Area*	Water (%)	Open Wetland (%)	Forest Wetland (%)	Forest ** (%)	Agriculture *** (%)	Industrial-Commercial (%)	Residential (%)	Transportation (%)	Other (%)
Coventry	62.2	2.6	64.8	4.2	1.5	4.5	69.7	7.6	0.9	8.5	0.2	2.9
Cranston	28.6	1.4	30.0	5.0	2.6	1.4	27.6	18.8	4.9	25.4	4.1	10.2
Exeter	57.6	0.6	58.2	1.0	1.1	3.9	79.3	8.1	0.1	2.3	-	2.1
Foster	51.4	0.8	52.2	1.6	0.7	5.0	81.0	8.4	0.2	2.4	-	0.7
Glocester	55.3	1.9	57.2	3.9	1.0	5.4	78.6	6.6	0.2	3.7	-	0.8
Johnston	23.7	0.7	24.4	3.0	3.5	2.0	59.1	9.3	2.0	16.0	1.7	3.4
Providence	18.1	1.9	20.0	9.5	0.2	-	4.1	1.0	17.3	41.5	9.1	17.7
Scituate	48.8	6.3	55.1	12.9	0.6	2.2	72.3	5.8	0.2	5.8	-	0.2
Warwick	34.9	0.9	35.8	2.6	1.6	0.7	24.6	9.5	5.5	37.8	6.7	11.0
West Greenwich	50.6	0.6	51.2	1.2	1.3	2.1	85.8	4.8	0.1	2.3	0.6	1.8
West Warwick	8.3	0.2	8.5	2.4	1.0	2.6	31.5	12.5	6.8	34.7	1.4	7.1

* U.S. Bureau of the Census data in square miles.
** Forest area excluding forest wetlands.
*** Intensive and extensive agriculture.

I-195 carries the Fall River-New Bedford-Cape Cod traffic. An extensive secondary State road system serves the other sections of the basin. Four interstate bus companies, 120 contract trucking firms, and local and regional buses service the area.

Railroad service, both bulk freight and passenger, connects Providence an the lower basin with Boston and New York.

Air passenger and air freight needs are handled at the State-operated T.F. Green airport, near the center of Warwick, with five major airlines operating over 100 flights daily.

Waterborne commerce is served by the Port of Providence, which has a 40-foot deep main channel and 21 terminals.

FUTURE DEVELOPMENT

Sizable population increases are projected for the inner ring of suburbs by 1990, particularly Johnston, Cranston, and Warwick. The outer ring of communities are also expected to grow substantially, especially Coventry, with its ready access from I-95. Table II-2 shows these projected population totals and growth rates.

Commercial and industrial construction can be expected to continue to meet these population increases. All of the communities in the lower basin have developed master plans to guide this growth in an orderly way and provide the necessary public services.

LAND USE WITHIN THE FLOOD PLAIN

For the purpose of this report the flood plain is considered to be that land subject to inundation at events approaching a Standard Project Flood. The intermediate regional flood plain is the land inundated at the one percent flood. Table II-5 summarizes the existing (1975) use of the flood plain and the available land currently zoned for the three major land use categories along the South Branch and the mainstem Pawtuxet River. Most of the available residential land is located in Coventry and West Warwick. Since the land use figures were complied, approximately 50 acres of industrial land have been developed, some of it below or at the hundred year flood levels. About 20 percent of the all existing commercial and industrial land in West Warwick, Cranston and Warwick is located in areas subject to inundation by the Pawtuxet River.

Most of the industrial-commercial usage is in complex type development. However, the complexes are so large that the entire mainstem of the Pawtuxet River could be considered one very large center, highly developed on both sides of the river, with only the river and housing tracts separating individual components.

PUBLIC AND PRIVATE PROGRAMS FOR MANAGING RESOURCES

The most common program for managing or preventing growth in this flood plain is the Flood Insurance Program. All of the basic communities are operating under either the regular or emergency program. To enter the regular program they, in effect, have instituted 100 year flood plain zoning. Another program that entails planning of the areas resources is the statewide Section 208 study conducted for areawide wastewater management. Various local conservation groups have set up site specific programs, as well as the local municipalities, to more carefully manage the area's natural resources.

Institutions involved in resource management control a significant area in the Pawtuxet Basin. The largest holder of a land area is the Providence Water Supply Board, which owns and operates the Scituate Reservoir complex on the North Branch. The Board owns about 25 square miles of lands, virtually all above the Scituate Reservoir. The State of Rhode Island also owns considerable land in the basin. Their Water Resources Board owns about 8,500 acres, 13.3 square miles of land at the location of the proposed Big River Reservoir. Several other large areas of land have been set aside as park complexes and are owned or operated by many public institutions. Some of the larger areas are Snake Den State Park, J.L. Curran Park, the George B. Pawker Woodland, Roger William Park, the Pawtuxet Reservation and Meshanticut State Park. The institutions owning these tracts of land should be able to insure that no development or changed conditions occur for the immediate future. In addition to these land holders, the Quidneck Reservoir Company owns and operates several fairly large water

impoundments, on the South Branch drainage area. The largest of these are Flat River Reservoir and Tiogue Lake. Their land holdings, however, are minimal. They are planning to develop small hydropower installations at some of their dams.

SIGNIFICANT ENVIRONMENTAL ELEMENTS

In the project region there are certain areas or specific sites which have significance from particular environmental aspects. The State of Rhode Island has identified approximately 220 places of special geological, botanical, hydrological, zoological or aesthetic interest throughout the State in a survey of unique natural areas which merit protection and conservation. This program is being directed by the New England Natural Resources Center. To our knowledge, as a result of our field studies, none of these sites will be impacted by any of the alternative plans.

There are numerous sites in the watershed that are currently listed on the National Register of Historic Places. There are also many sites or areas with historic significance which are being considered for inclusion in the Register. Three of these; Nooseneck Mill Sites, New London Turnpike, and Sweet Sawmill Road are situated in the Big River Reservoir project area. If the reservoir were built, portions of the remaining mill foundations would be inundated, while others would be above the permanent pool.

There are no specific, unique, environmental elements in either the proposed Warwick Avenue Local Protection area or the Norwood area that would be impacted by construction. The Big River Reservoir project area does possess certain areas dominated by coniferous forest. The forthcoming feasibility report on Big River will discuss all significant environmental elements in detail.

WITHOUT CONDITION PROFILE

The condition most likely to occur in the basin without any Federal action will be continued growth. With the advent of the Flood Insurance Program the trend of unwise development of the intermediate flood plan should be reduced, but not eliminated. Development will continue to occur in the land area between the 100-year flood and the Standard Project Flood. Losses can therefore be expected to increase although not in the same proportion as prior to the initiation of the Flood Insurance Program and flood plain zoning.

The entire basin is experiencing rapid growth. As such, the runoff rate will increase substantially, causing higher flood peaks than previously experienced. Development that is now flood free at a hundred year flood could get damaged at a fifty year event due to this

urbanization. The assumptions used to derive the future hydraulic conditions were that the communities will adhere to the zoning required under the Flood Insurance Program. No loss of natural valley storage was anticipated. If the zoning is not adhered to and the flood plain is filled along with upstream holding areas, the situation will worsen and greater increases in flood stages can be anticipated. Even with wise development, the lower Pawtuxet's flood problems will significantly worsen. More frequent flooding can be expected with a larger area subject to inundation.

Problems on the North and South Branches will not be as intense as those on the mainstem. The lower reaches of the Meshanticut Brook and the Pocasset River will experience the same problems as the mainstem in addition to the increased runoff from upstream areas. They will also feel the effects of increased stages on the Pawtuxet as those tributaries will not be able to discharge flows as quickly and this will result in increased heights.

PROBLEMS, NEEDS AND OPPORTUNTIES

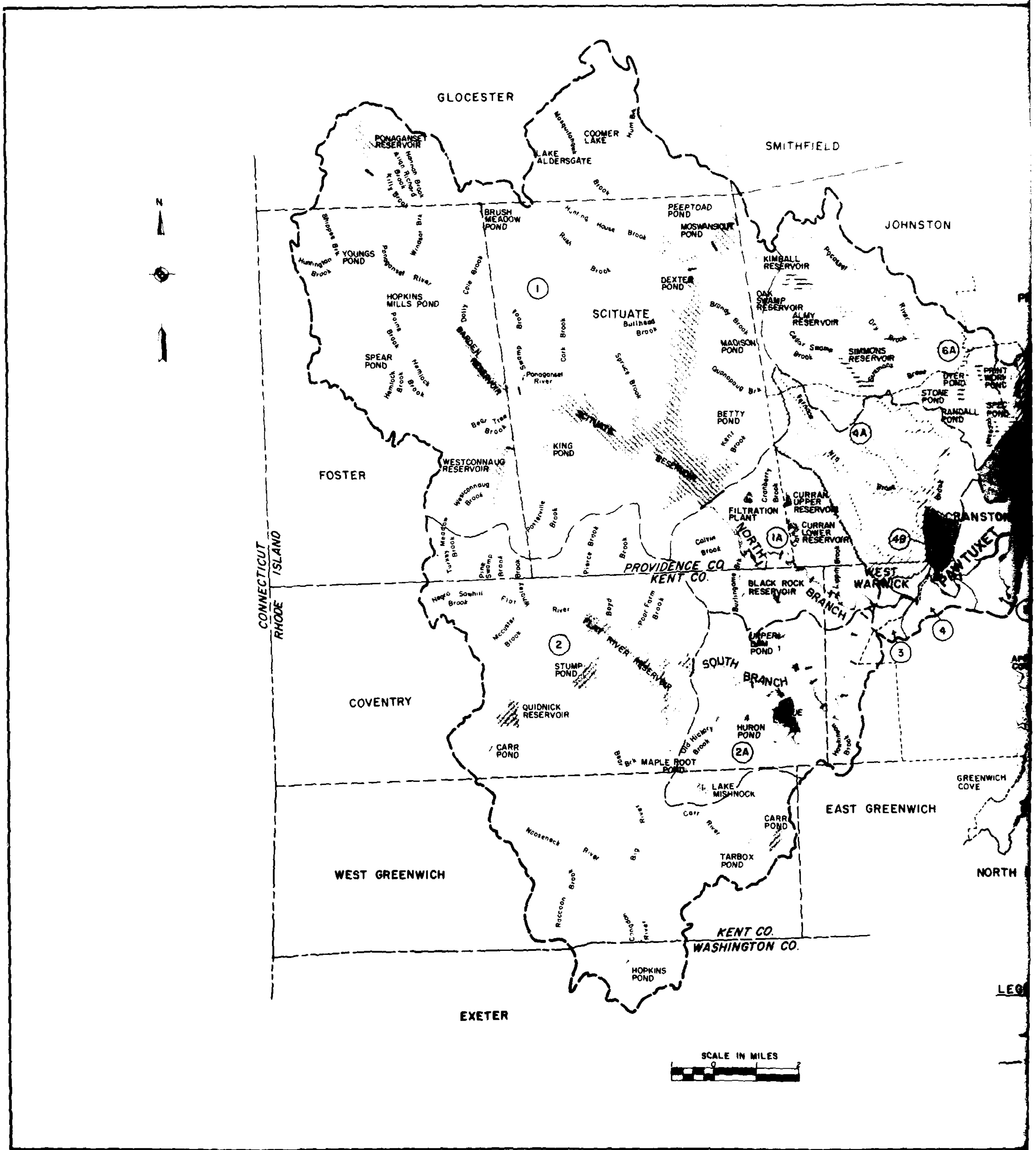
The Pawtuxet River has been subdivided into sixteen damage zones, shown on Plate II-2. Only problems relating to flood damage potential are discussed herein. Five of the zones have minor or negligible annual damages and have been eliminated from further consideration as part of a basin management plan. These consist of the area upstream of Scituate Reservor, Zone 1; the area upstream of Flat River Reservoir, Zone 2; the area between Riverpoint, the merging point of the North and South Branch, down to the Natick Dam on the Pawtuxet mainstem; the headwaters and upper reaches of Meshanticut Brook, Zone 4A; and the upper reaches of Roger Williams Brook, Zone 7A. The remaining 11 damage zones are described as follows:

Tributary Streams

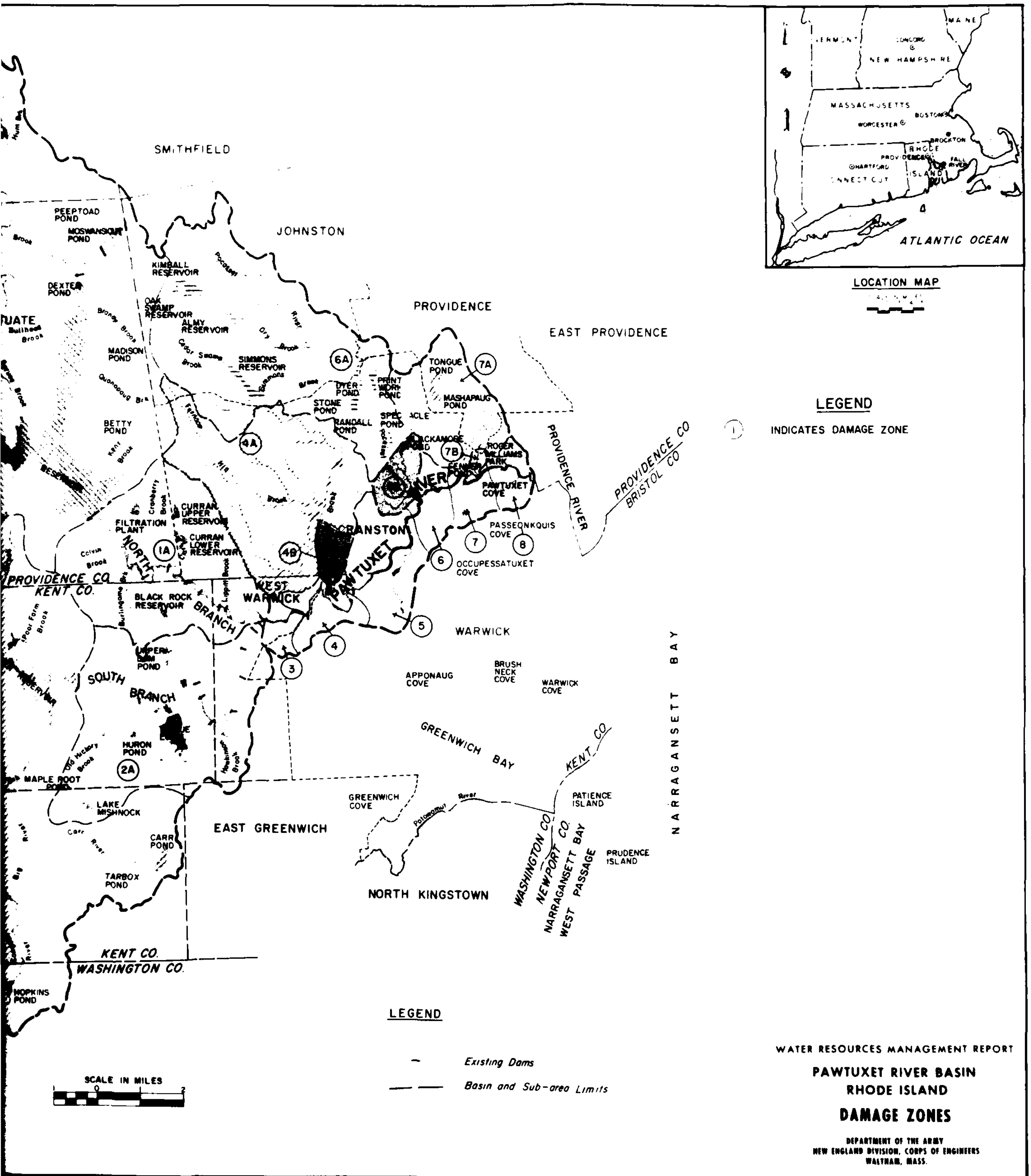
Zone 1A - This reach begins at the Memorial Dam impoundment at Scituate Reservoir and terminates at the confluence with the South Branch in Riverpoint. Potential for damages do exist, but the affected structures are dispersed throughout the river's reach.

Zone 2A - This area begins at the dam controlling Flat River Reservoir and runs downstream to the confluence with the North Branch at Riverpoint. The major damage area in its reach is the America Hoescht, where several structures could experience losses. Overall, damages are slight.

Zone 4B - Meshanticut Brook - This reach commences at the I-295 bridge crossing south of Wilbar Avenue and ends at the normal confluence with the Pawtuxet River. Damages at this reach are confined mainly to residential type structure and contractor's storage yards. Most of the flooding is due to backwater of the Pawtuxet.



GLOCESTER
SMITHFIELD
JOHNSTON
FOSTER
SCITUATE
COVENTRY
WEST GREENWICH
EAST GREENWICH
EXETER
CRANSTON
WEST WARWICK
NORTH
GREENWICH COVE
CONNECTICUT
RHODE ISLAND
PROVIDENCE CO.
KENT CO.
WASHINGTON CO.
PONAGANSET RESERVOIR
COOMER LAKE
LAKE ALDERSGATE
BRUSH MEADOW POND
PEEPTOAD POND
MOSWANSICUT POND
YOUNGS POND
HOPKINS MILLS POND
SPEAR POND
KIMBALL RESERVOIR
OAK SWAMP RESERVOIR
ALMY RESERVOIR
DEXTER POND
MADISON POND
SIMMONS RESERVOIR
BETTY POND
KING POND
WESTCONNAUG RESERVOIR
FILTRATION PLANT
CURRAN UPPER RESERVOIR
CURRAN LOWER RESERVOIR
BLACK ROCK RESERVOIR
DYER POND
STONE POND
RANDALL POND
UPPER DAM POND
SOUTH BRANCH
NORTH BRANCH
PAWTUXET
STUMP POND
QUIDNICK RESERVOIR
FLAT RIVER RESERVOIR
SCITUATE RESERVOIR
BARDEN RESERVOIR
CARR POND
HURON POND
MAPLE ROOT POND
LAKE MISHNOCK
TARBOX POND
HOPKINS POND
Ponaganset River
Hunting House Brook
Rush Brook
Bullhead Brook
Spruce Brook
Quanapaug Brk
Kent Brook
Cranberry Brook
Calvin Brook
Pierce Brook
Westconnaug Brook
Bear Tree Brook
Hemlock Brook
Huntington Brook
Windsor Brk
Dolly Cole Brook
Cork Brook
Swamp Brook
Flat River
Poor Farm Brook
Mccuster Brook
Old Hickory Brook
Nooseneck River
Big River
Raccoon Brook
Carr River
Dry Brook
Cedar Swamp Brook
1
1A
2
2A
3
4
4A
4B
6A
N
SCALE IN MILES
0
2



SMITHFIELD
JOHNSTON
PROVIDENCE
EAST PROVIDENCE
PEEPTOAD POND
DEXTER POND
KIMBALL RESERVOIR
OAK SWAMP RESERVOIR
ALMY RESERVOIR
MADISON POND
SIMMONS RESERVOIR
BETTY POND
DYER POND
STONE POND
RANDALL POND
PRINT WORKS POND
SPEC POND
TONGUE POND
MASHAPAUG POND
ROGER WILLIAMS PARK
PAWTUXET COVE
PASSEONKQUIS COVE
OCCUPESSATUXET COVE
CRANSTON
PAWTUXET
PROVIDENCE RIVER
PROVIDENCE CO
BRISTOL CO
FILTRATION PLANT
CURRAN UPPER RESERVOIR
CURRAN LOWER RESERVOIR
NORTH BRANCH
PROVIDENCE CO
KENT CO.
BLACK ROCK RESERVOIR
WEST WARWICK
WARWICK
SOUTH BRANCH
HURON POND
MAPLE ROOT POND
LAKE MISHNOCK
CARR POND
TARBOX POND
EAST GREENWICH
APPONAUG COVE
BRUSH NECK COVE
WARWICK COVE
GREENWICH BAY
GREENWICH COVE
KENT CO
PATIENCE ISLAND
PRUDENCE ISLAND
WASHINGTON CO
NEWPORT CO
NARRAGANSETT BAY
WEST PASSAGE
NORTH KINGSTOWN
NARRAGANSETT BAY
KENT CO.
WASHINGTON CO.
HOPKINS POND
1A
2A
3
4
4A
4B
5
6
6A
7
7A
7B
8
LEGEND
INDICATES DAMAGE ZONE
VERMONT
NEW HAMPSHIRE
MAINE
MASSACHUSETTS
WORCESTER
BOSTON
BROCKTON
RHODE ISLAND
PROVIDENCE
FALL RIVER
HARTFORD
CONNECTICUT
ATLANTIC OCEAN
LOCATION MAP
LEGEND
Existing Dams
Basin and Sub-area Limits
SCALE IN MILES
0
2
WATER RESOURCES MANAGEMENT REPORT
PAWTUXET RIVER BASIN
RHODE ISLAND
DAMAGE ZONES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE II-2

Zone 6A - Upper Pocasset River - Within this portion of the Pocasset, running from the headwaters downstream to Reservoir Avenue in Cranston, potential damage areas are mainly residential, including both single family and multi-unit structures. At an intermediate flood event, portions of Rotary Drive, LaFazia Drive, Center Street, and Middle Street all in Johnston, and Dyer Street in Cranston are inundated. Commerical-Industrial losses are potential at portions of Dyer Street, at Cranston Print Works, Cranston Street, Knollwood Avenue and Fletcher Avenue.

Zone 6B - Lower Pocasset River - Beginning at Reservoir Avenue, it extends downstream until it flows into the Pawtuxet River. Other than some minor commercial losses along Reservoir Avenue and the Cranston Press on Pontiac Avenue, losses are felt mainly by new multi-unit residential type establishments that have been built unwisely within the intermediate flood limits. Most of the losses are attributable to clean up costs, replacement/repair of heating plant equipment, laundry rooms, and workshops. However, some multi-unit complexes can have occupied basement units under water. The flooding in this zone is caused by backwater conditions of the Pawtuxet River.

Zone 7B - Roger William Brook - This reach begins at Park Avenue and terminates at the Pawtuxet River. The flooding in this zone is also caused by backwater conditions of the Pawtuxet. The main areas that would be damaged are the Atlantic Tubing Company and Ciba-Geigy complex. Flooding in this reach as opposed to the flooding of Zone 7 itself is difficult to separate.

Pawtuxet River Mainstem

Damages along the reaches of the mainstem are extremely high. There are about 2,000 various types of structures subject to inundation from storms ranging from a yearly event up to a Standard Project Flood. Descriptions of damages by zones are discussed in the following paragraphs. Plates II-3 and II-4 show these flooded areas.

Zone 4 - This area begins just downstream of the Natick Dam in Warwick-West Warwick and terminates at the Pontiac Dam in Warwick. Areas subject to flooding extend along the entire length of the zone. A very high concentration of damages exists in the Midland Mall and Warwick Mall areas, surrounding stores, and an apartment complex. Also of concern is the West Warwick sewage treatment plant. This is due to possible water quality degradation caused by inundation.

Zone 5 - Starting at the terminus of Zone 4, this zone ends at the location of the U.S.G.S. gaging station in Cranston. Damages in this reach are not as severe as in Zone 4. Most of the annual damages are sustained by the Pontiac Print Works and the Bulova Watch Company. Both of these major firms can sustain moderate damage at events

as frequent as the 15-year storm. Another major concern is the Warwick sewage treatment plant. The chlorine contact tank can be flooded by almost the yearly type event. Although physical damage is minor, the unit is shut down and the unchlorinated but treated effluent enters the Pawtuxet. At between a 5 and 10-year frequency flood, the settling tanks and aeration units can become inundated. Although the physical losses mount up with each incremental height of water, the total losses are still relatively minor.

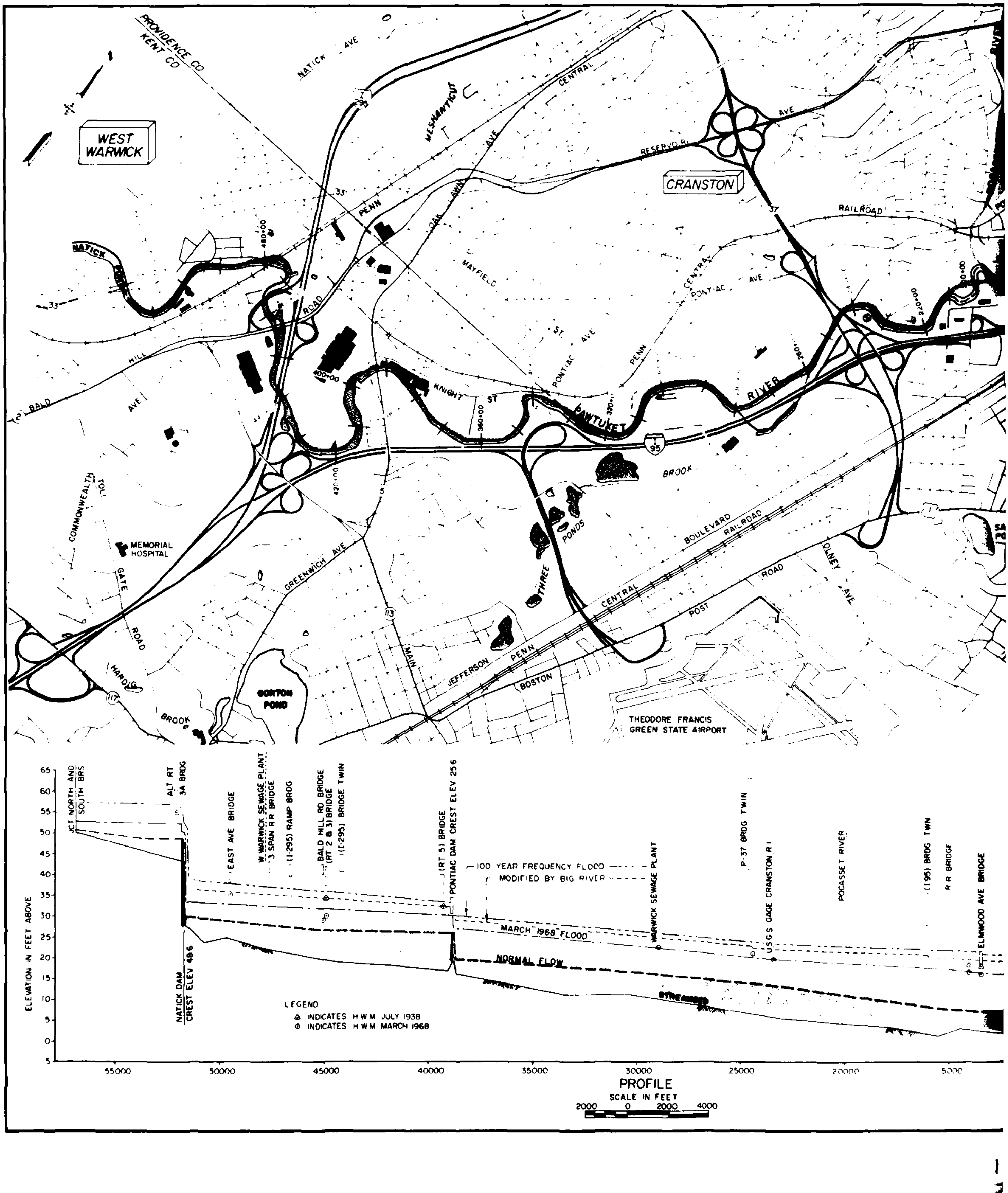
Zone 6 - This reach extends downstream to the Elmwood Avenue Bridge in Warwick-Cranston. Damages in this zone are the smallest of all the mainstem reaches with the exception of Zone 3. The Jefferson Avenue Industrial Park in Warwick consisting of Edward Electronic, Ryder Truck Rental Company, and Colony Ford Company does sustain heavy damages, with the initial losses starting at about a 10- year flood event. Also in this area is a major electrical transformer substation. This station would be inoperable during a 50-year event and major rerouting of electricity would be necessary.

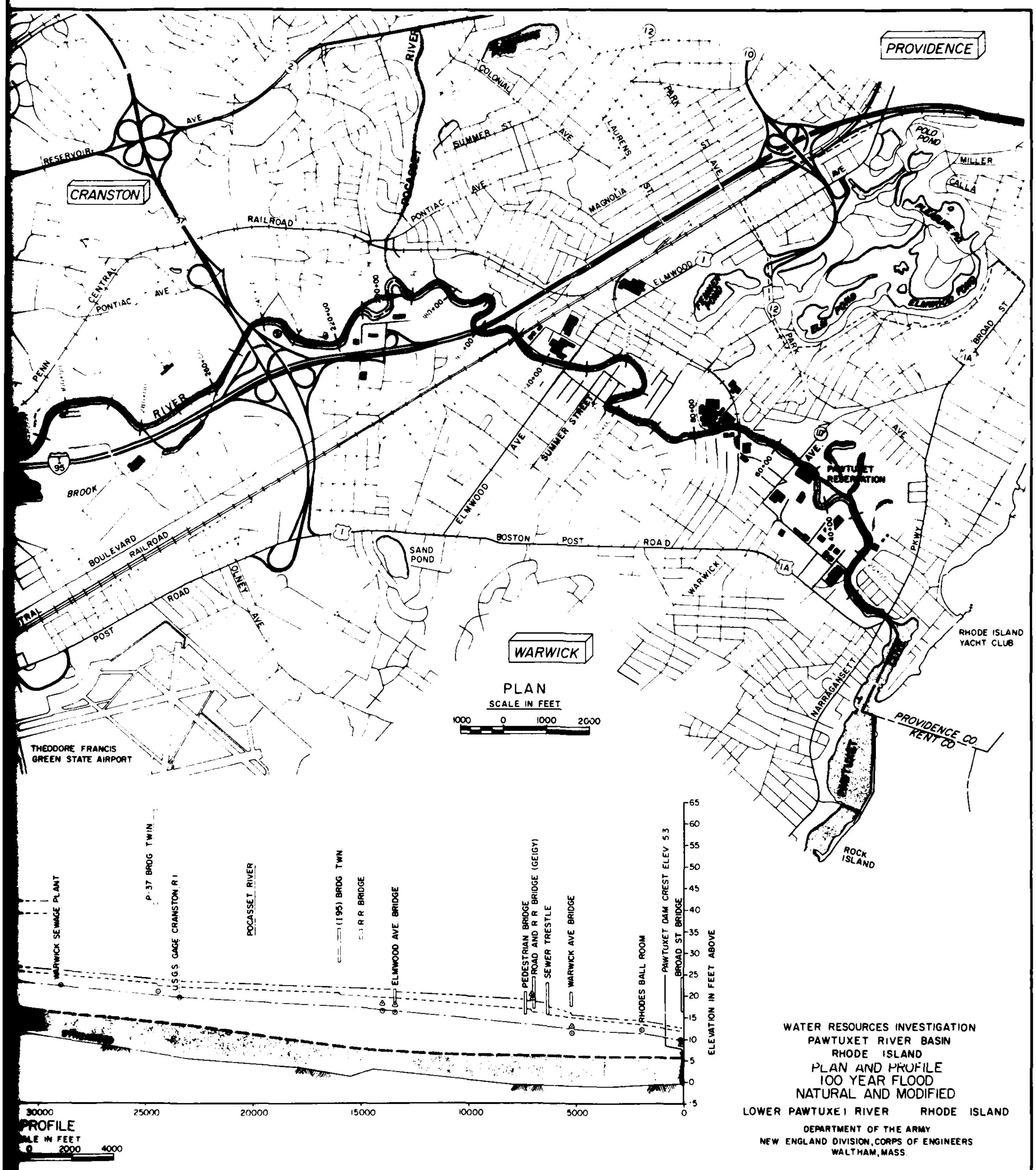
Another industrial park, Wellington Avenue in Cranston has experienced past damages from the 1968 flood a 10- to 15-year event. Some intensified use of the various industrial outbuildings by a glass storage warehouse and the Elmwood Sensors Company will result in much higher, recurring type losses. A moderately large lumber yard on the opposite bank in Warwick is also flood prone. Its losses depend on the amount of immovable material in storage at the time flooding occurs.

Zone 7 - This area sustains extremely high annual damages. From the termination point of Zone 6, it extends downstream to the sewer trestle crossing the Pawtuxet and the Ciba-Geigy Complex. Very high damages are possible at this location, particularly on the Cranston side. Damages would begin at about a fifteen year event. The Atlantic Tubing complex, in Cranston, which can also become flooded by backwater from Zone 7B, is also likely to sustain heavy damages.

An extremely flood-prone residential area is located in Warwick. Locally known as the Belmont or Norwood area, this site located off Elmwood Avenue has about 50 homes that would sustain moderate damage at a hundred year flood. If a small dike, constructed by the Corps of Engineers in 1970 with Emergency Operations funds, did not exist, the area would be flooded annually. The dike, which was recently overtopped, provides protection to about a fifteen year flood level. The 100-year flooded area is shown on Plate II-5.

Zone 8 - Damages in this zone are also extremely heavy. Flooding occurs from either the Pawtuxet River flows or from storm driven tides in Narragansett Bay. This damage area extends from the sewer trestle at Ciba-Geigy and ends at the Broad Street Dam at the head

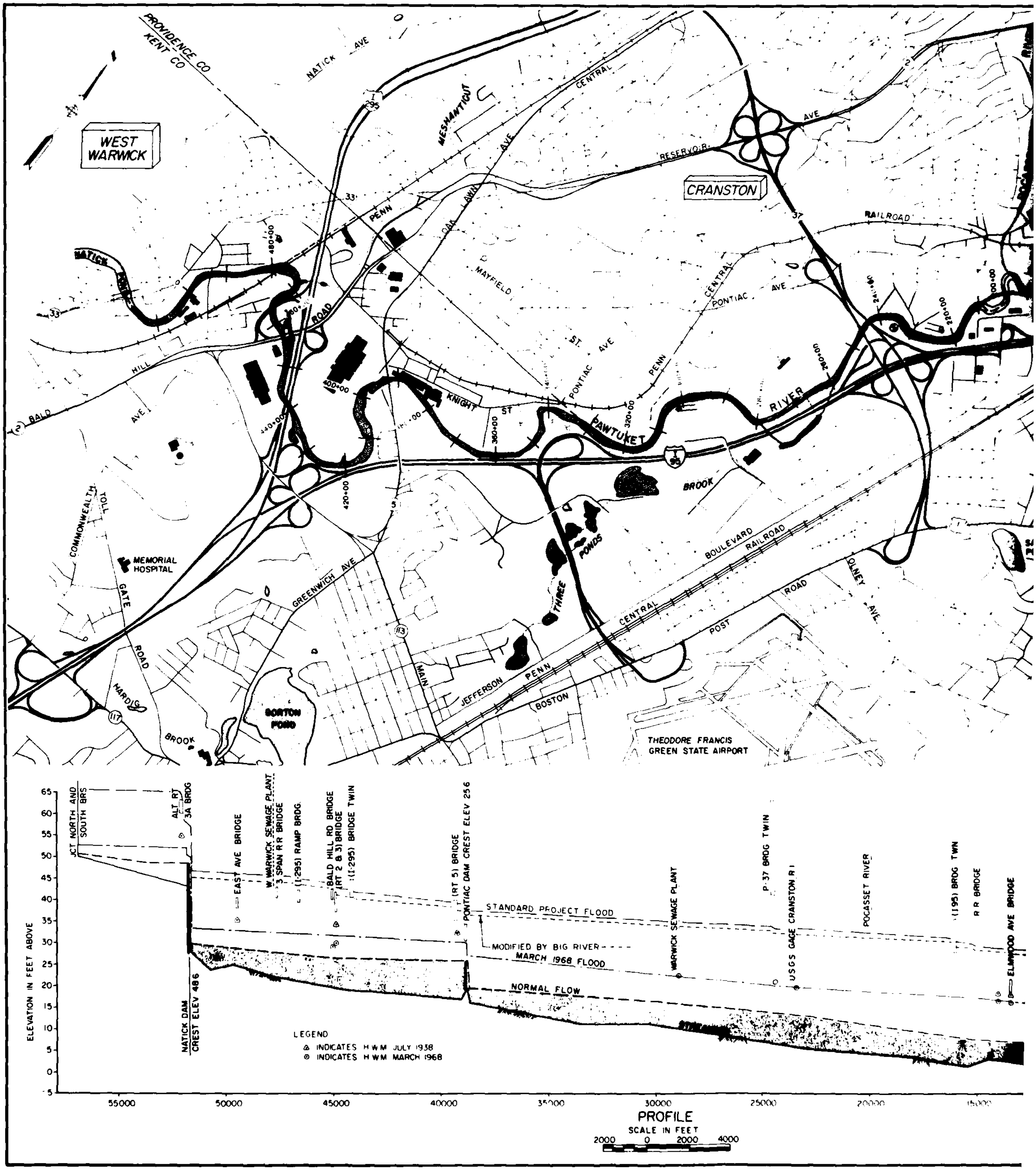

WEST WARWICK
CRANSTON
PROVIDENCE CO
KENT CO
NATICK AVE
MESHANTICUT
CENTRAL
RESERVOIR AVE
RAILROAD
PENN
OAK LAWN AVE
MAYFIELD
PONTIAC AVE
BALD HILL ROAD
KNIGHT ST
PAWTUXET RIVER
BROOK
THREE PONDS
COMMONWEALTH
MEMORIAL HOSPITAL
TOLL GATE ROAD
GREENWICH AVE
MAIN
JEFFERSON
BOULEVARD
POST ROAD
BOSTON
OLNEY AVE
HARDIG BROOK
GORTON POND
THEODORE FRANCIS GREEN STATE AIRPORT
ELEVATION IN FEET ABOVE
JCT NORTH AND SOUTH BRS
ALT RT 3A BRDG
EAST AVE BRIDGE
W WARWICK SEWAGE PLANT
3 SPAN R R BRIDGE
I(I-295) RAMP BRDG
BALD HILL RD BRIDGE (RT 2 & 3) BRIDGE
I(I-295) BRIDGE TWIN
(RT 5) BRIDGE
PONTIAC DAM CREST ELEV 256
100 YEAR FREQUENCY FLOOD
MODIFIED BY BIG RIVER
MARCH 1968 FLOOD
NORMAL FLOW
STREAMBED
WARWICK SEWAGE PLANT
P-37 BRDG TWIN
USGS GAGE CRANSTON R I
POCASSET RIVER
I(95) BRDG TWN
R R BRIDGE
ELMWOOD AVE BRIDGE
NATICK DAM CREST ELEV 486
LEGEND
INDICATES H W M JULY 1938
INDICATES H W M MARCH 1968
55000
50000
45000
40000
35000
30000
25000
20000
15000
PROFILE
SCALE IN FEET
2000 0 2000 4000



WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND
PLAN AND PROFILE
100 YEAR FLOOD
NATURAL AND MODIFIED
LOWER PAWTUXET RIVER RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE II-3



WEST WARWICK
CRANSTON
PROVIDENCE CO
KENT CO
NATICK AVE
MESHANTICUT
CENTRAL AVE
RESERVOIR
RAILROAD
PENN
OAK LAWN AVE
MAYFIELD
PONTIAC AVE
ST.
BALD HILL ROAD
KNIGHT ST
PAWTUXET RIVER
BROOK
THREE PONDS
COMMONWEALTH
TOLL GATE ROAD
MEMORIAL HOSPITAL
GREENWICH AVE
MAIN
JEFFERSON
BOULEVARD
POST ROAD
OLNEY AVE
BOSTON
HARDIG BROOK
GORTON POND
THEODORE FRANCIS GREEN STATE AIRPORT
ELEVATION IN FEET ABOVE
JCT NORTH AND SOUTH BRS
ALT RT 3A BRDG
NATICK DAM CREST ELEV 48.6
EAST AVE BRIDGE
W. WARWICK SEWAGE PLANT
3 SPAN R.R BRIDGE
(I-295) RAMP BRDG.
BALD HILL RD BRIDGE (RT 2 & 3) BRIDGE
(I-295) BRIDGE TWIN
(RT 5) BRIDGE
PONTIAC DAM CREST ELEV 25.6
STANDARD PROJECT FLOOD
MODIFIED BY BIG RIVER
MARCH 1968 FLOOD
NORMAL FLOW
WARWICK SEWAGE PLANT
P-37 BRDG TWIN
USGS GAGE CRANSTON R.I.
POCASSET RIVER
(I-95) BRDG TWN
R.R BRIDGE
ELMWOOD AVE BRIDGE
LEGEND
△ INDICATES H.W.M. JULY 1938
⊙ INDICATES H.W.M. MARCH 1968
55000
50000
45000
40000
35000
30000
25000
20000
15000
PROFILE
SCALE IN FEET
2000 0 2000 4000

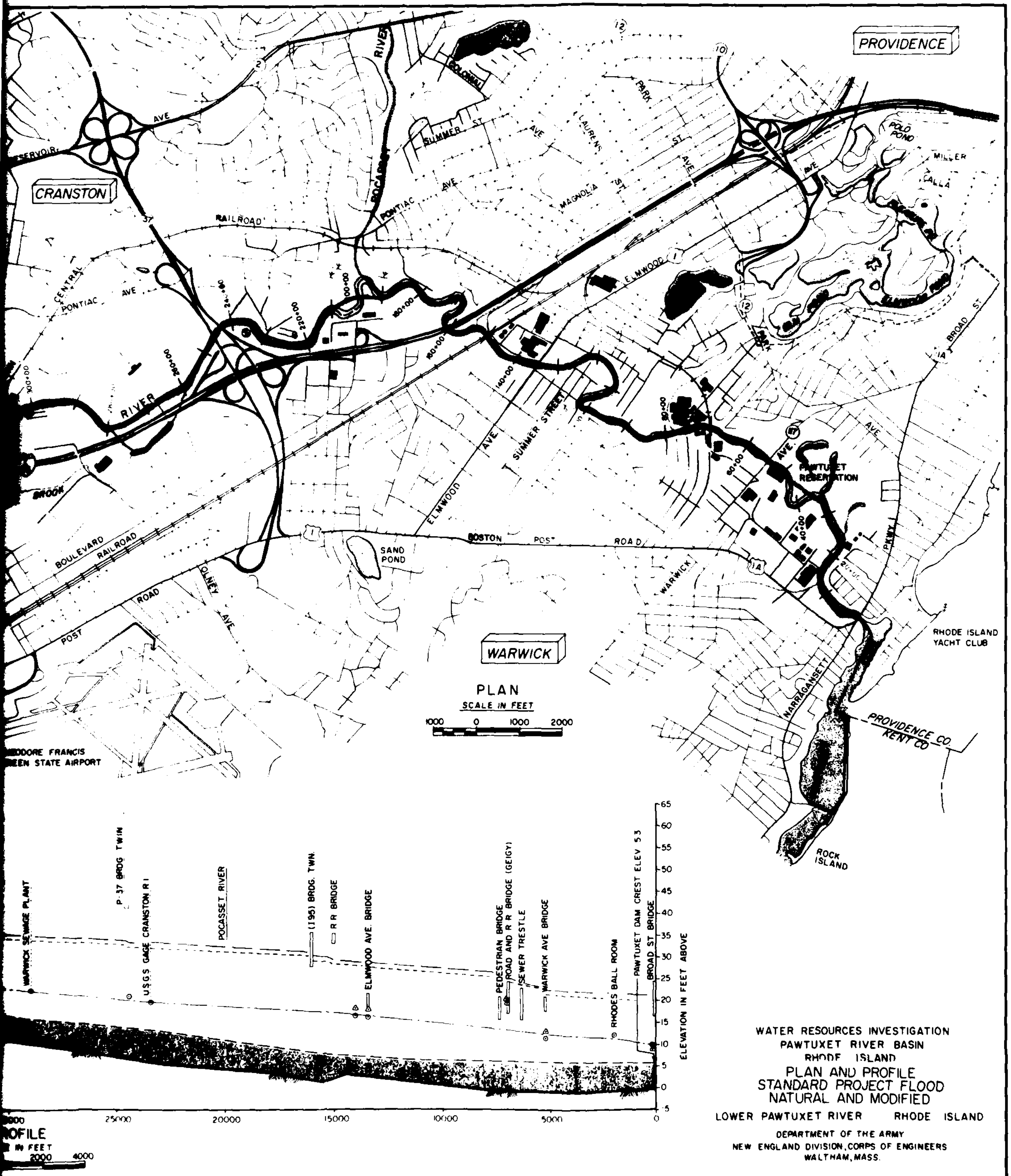
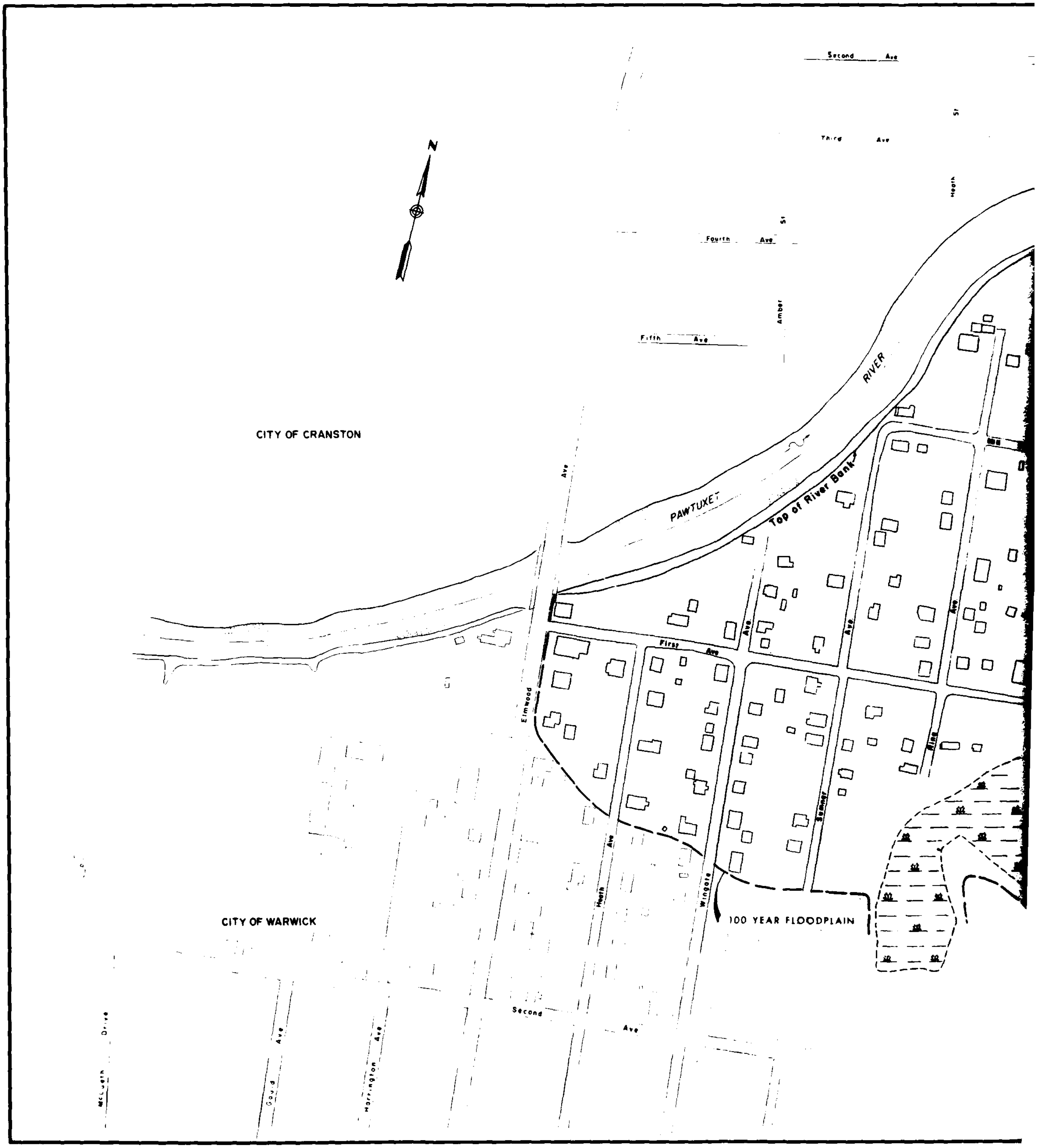
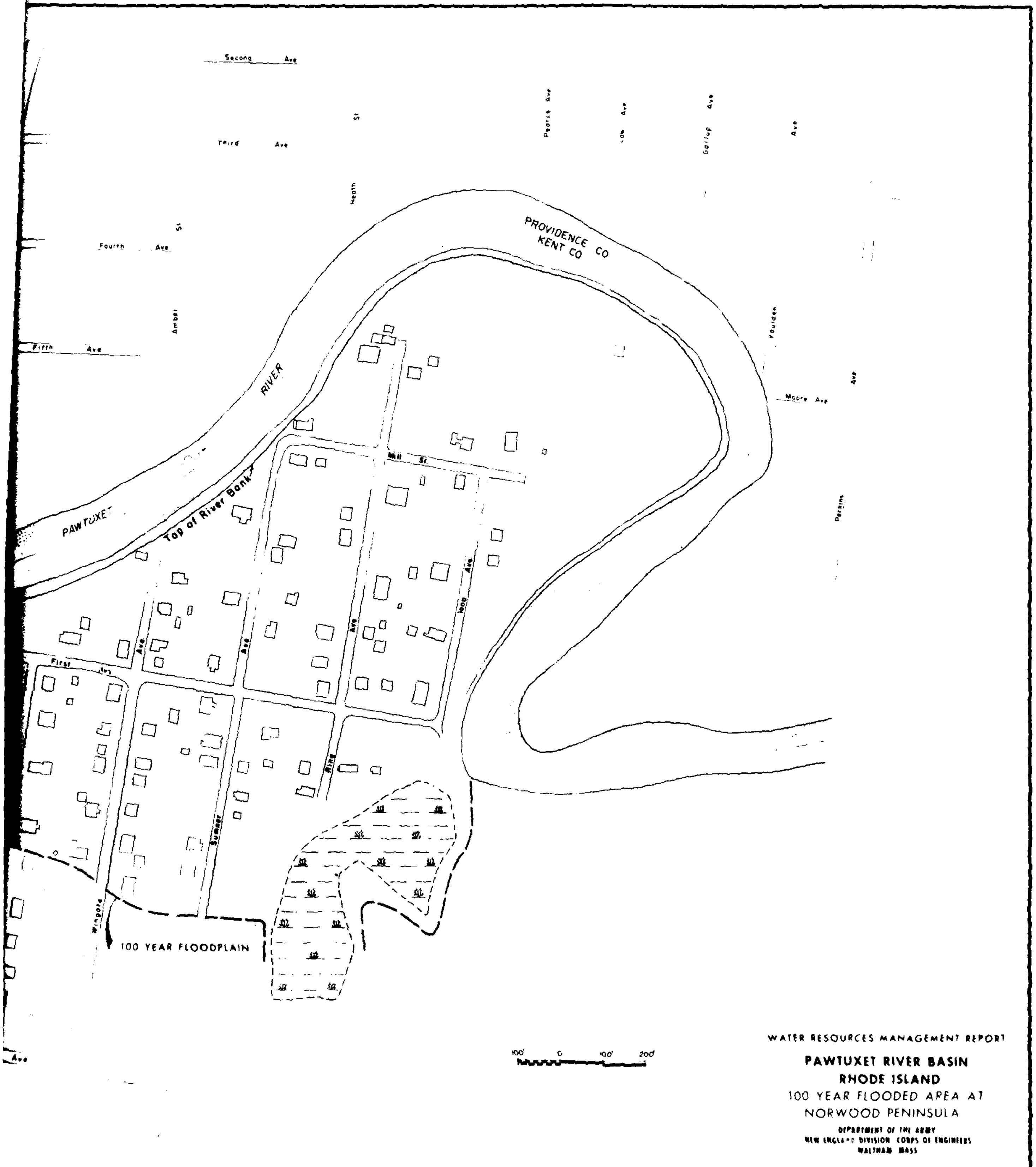

PROVIDENCE
CRANSTON
WARWICK
PLAN
SCALE IN FEET
1000 0 1000 2000
RESERVOIR AVE
PONTIAC AVE
RAILROAD
CENTRAL
SUMMER ST
LAURENS
PARK
MAGNOLIA ST
ELMWOOD
POLO POND
MILLER
CALLA
BROAD ST
RIVER
BROOK
BOULEVARD
RAILROAD
ELMWOOD AVE
SUMMER STREET
PAWTUXET RESERVATION
SAND POND
BOSTON POST ROAD
POST ROAD
OLNEY AVE
WARWICK
NARRAGANSETT
PKWY
RHODE ISLAND YACHT CLUB
PROVIDENCE CO
KENT CO
ROCK ISLAND
THEODORE FRANCIS GREEN STATE AIRPORT
WARWICK SEWAGE PLANT
P-37 BRDG TWIN
U.S.G.S GAGE CRANSTON R.I.
POCASSET RIVER
(I 95) BRDG. TWN.
R R BRIDGE
ELMWOOD AVE. BRIDGE
PEDESTRIAN BRIDGE
ROAD AND R R BRIDGE (GEIGY)
SEWER TRESTLE
WARWICK AVE BRIDGE
RHODES BALL ROOM
PAWTUXET DAM CREST ELEV 53
BROAD ST BRIDGE
ELEVATION IN FEET ABOVE
25000
20000
15000
10000
5000
0
PROFILE
SCALE IN FEET
2000 4000
WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND
PLAN AND PROFILE
STANDARD PROJECT FLOOD
NATURAL AND MODIFIED
LOWER PAWTUXET RIVER RHODE ISLAND
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE II-4


CITY OF CRANSTON
CITY OF WARWICK
PAWTUXET RIVER
Top of River Bank
100 YEAR FLOODPLAIN
N
Second Ave
Third Ave
Fourth Ave
Fifth Ave
First Ave
Elmwood Ave
Heath Ave
Wingate
Sumner
Amber St
Heath St
McGuirk Drive
Gould Ave
Harrington Ave



WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

100 YEAR FLOODED AREA AT
NORWOOD PENINSULA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

PLATE II 5

of Pawtuxet Cove. Other than the Pawtuxet Reservation conservation land in Cranston and a one-quarter mile strip of high undevelopable land on the rivers edge between the dam and ITT Hammel Dahl Corporation in Warwick, the remaining land is highly developed and flood-prone. The entire south bank in Warwick, other than the above mentioned high river's edge, is occupied by the Warwick Industrial Park, which consists of 15 individual structures housing over 30 primarily industrial concerns. Each is situated at or within one foot of the hundred year flood stage. Two concerns could receive especially high losses: Sealol and ITT Hammel Dahl. Plates II-6 and II-7 show the flooded areas at a 100-year and Standard Project Flood, respectively.

PLANNING CONSTRAINTS

- As the lower portion of the basin is highly urban, any location protective measure must provide for Standard Project Flood protection.

- Any channel improvements cannot worsen conditions upstream or downstream without provisions for mitigation.

- Existing reservoirs are not available for flood control storage due to present usage and project life.

- Environmental impacts of out-of-basin transfer of waters must be assessed if recommended.

- For benefit calculation purposes, all new growth must adhere to the provisions of the National Flood Insurance Policy as required by law.

PLANNING OBJECTIVES

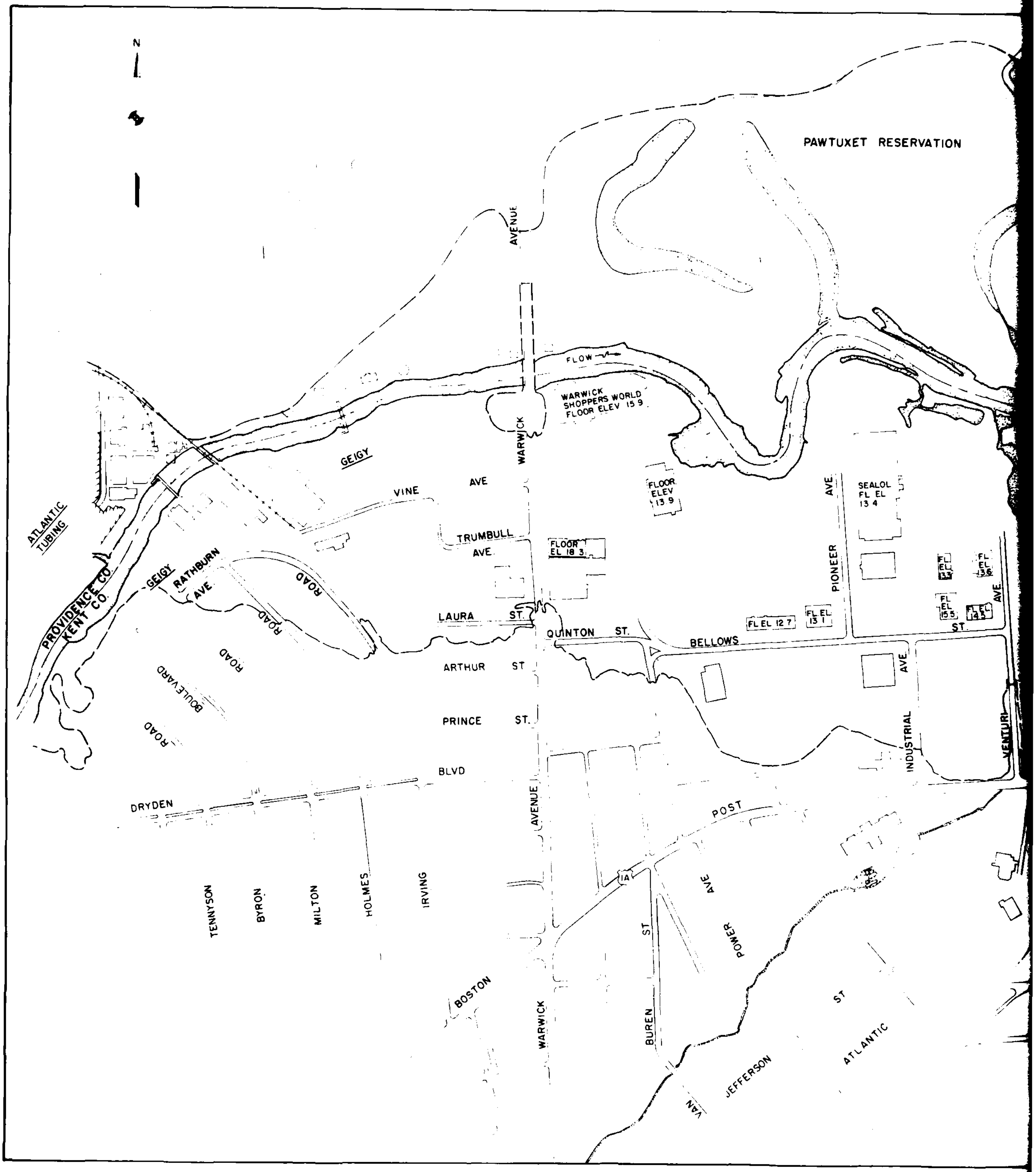
- Reduce existing flood losses in the Pawtuxet River Basin.

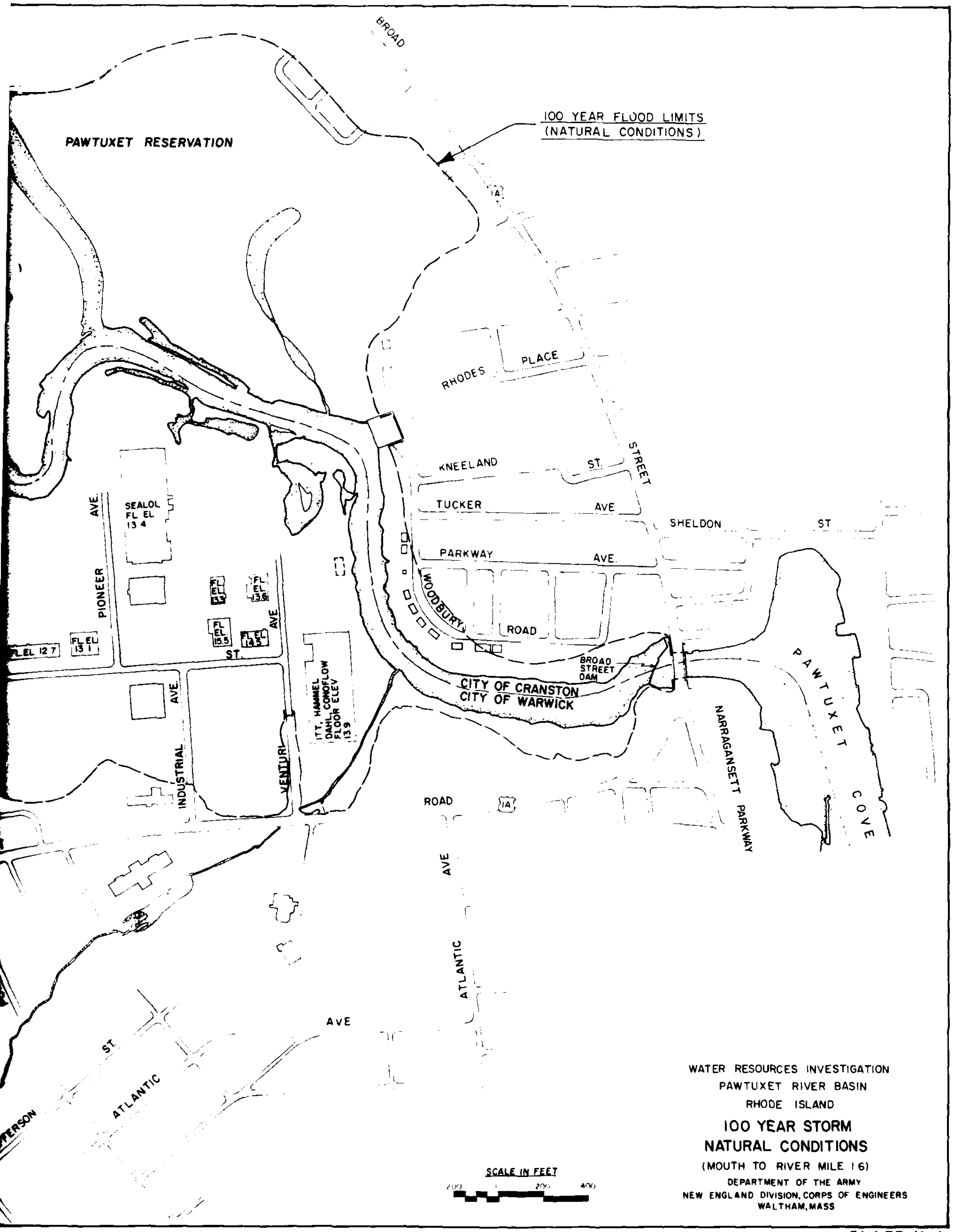
- Minimize impacts to existing natural resources.

- Alert flood plain inhabitants and the general public to the dangers of flooding in the Pawtuxet River Basin.

- Reduce social impacts to residents of the Norwood-Belmont Park area from the trauma of continual inundation caused by almost yearly flooding of the Pawtuxet River.

- Minimize the potential for future additional losses to presently undeveloped lands.


N
PAWTUXET RESERVATION
AVENUE
FLOW
WARWICK SHOPPERS WORLD FLOOR ELEV 15 9
WARWICK
GEIGY
VINE
AVE
FLOOR ELEV 13 9
PIONEER AVE
SEALOL FL EL 13 4
ATLANTIC TUBING
TRUMBULL AVE
FLOOR EL 18 3
FL EL 13 6
GEIGY
RATHBURN AVE
ROAD
ROAD
PROVIDENCE CO.
KENT CO.
LAURA ST.
QUINTON ST.
BELLOWS
FL EL 12 7
FL EL 13 1
FL EL 15 5
FL EL 14 5
ST.
ROAD
BOULEVARD
ROAD
ARTHUR ST
PRINCE ST.
AVE
INDUSTRIAL
VENTURI
BLVD
DRYDEN
AVENUE
POST
1A
TENNYSON
BYRON
MILTON
HOLMES
IRVING
AVE
ST
POWER
BOSTON
WARWICK
BUREN
VAN
JEFFERSON
ST
ATLANTIC

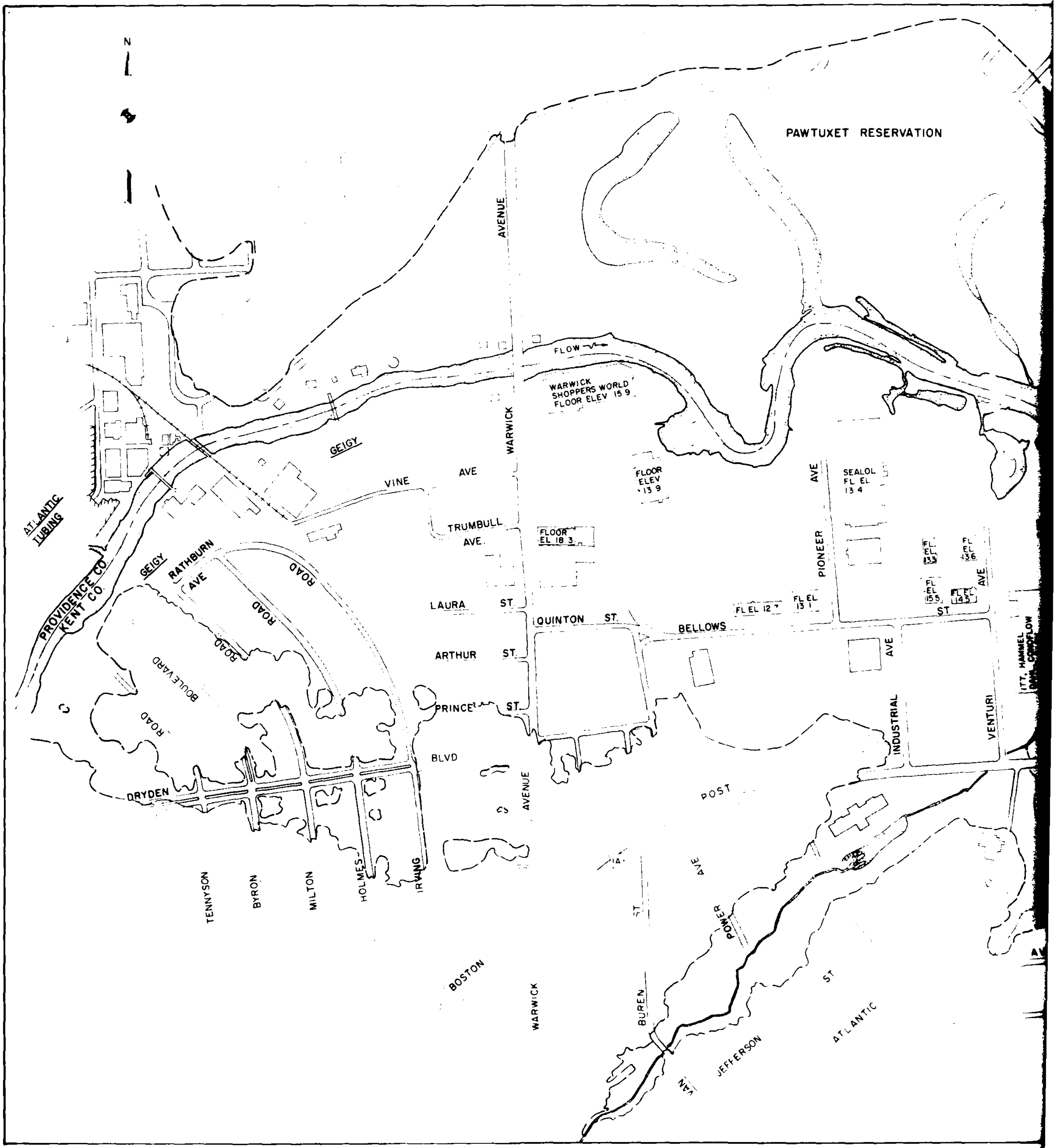


WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND

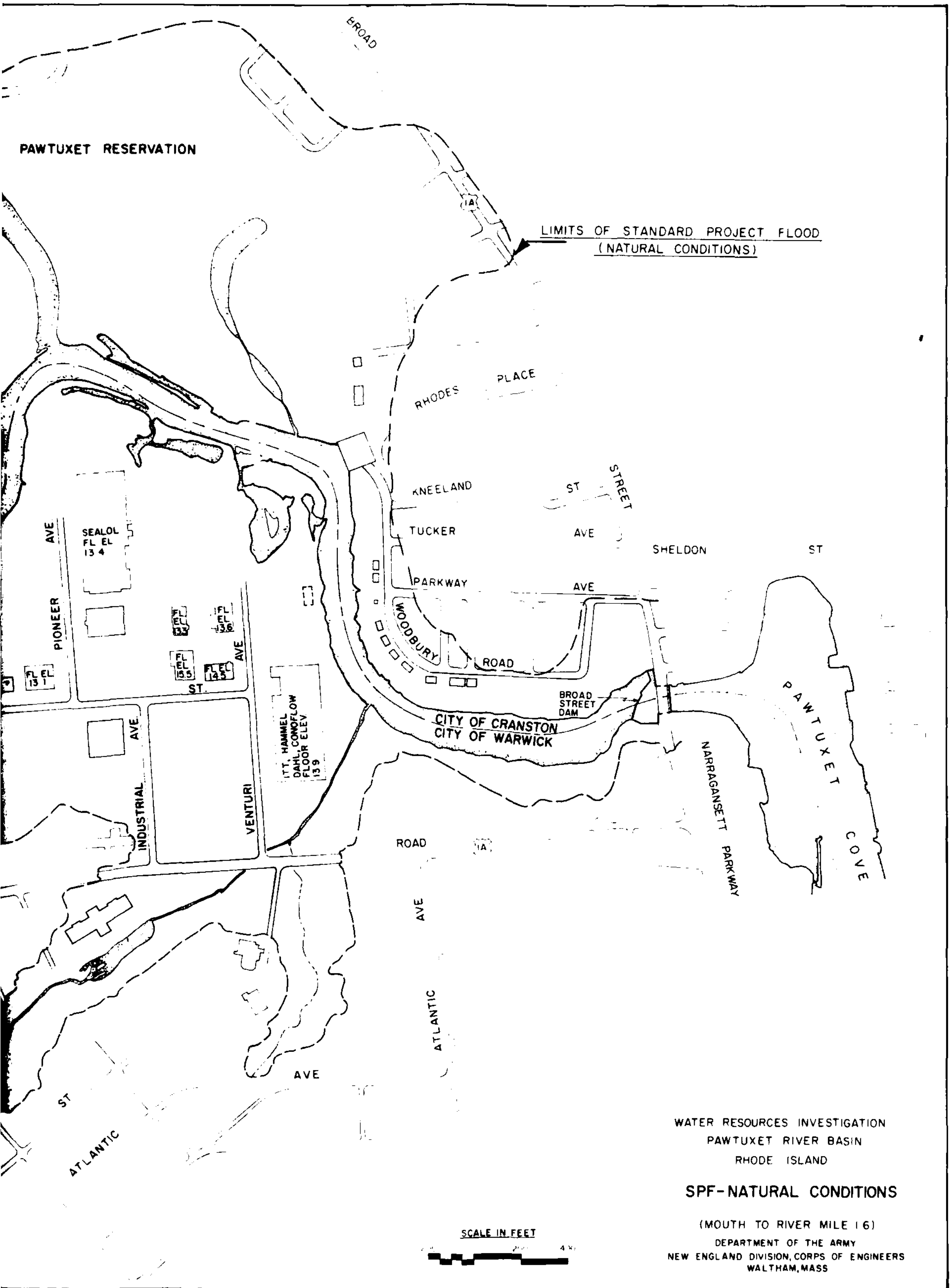
100 YEAR STORM
NATURAL CONDITIONS
(MOUTH TO RIVER MILE 1.6)

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

PLATE II-6



N
PAWTUXET RESERVATION
AVENUE
FLOW
WARWICK SHOPPERS WORLD FLOOR ELEV 15.9
WARWICK
GEIGY
VINE
AVE
FLOOR ELEV 13.9
SEALOL FL EL 13.4
AVE
ATLANTIC TUBING
TRUMBULL AVE.
FLOOR EL 18.3
PIONEER
FL EL 13.3
FL EL 13.6
PROVIDENCE CO.
KENT CO.
GEIGY
RATHBURN AVE
ROAD
ROAD
ROAD
LAURA ST.
QUINTON ST.
BELLOWS
FL EL 12.7
FL EL 13.1
FL EL 15.5
FL EL 14.5
ST
AVE
BOULEVARD
ARTHUR ST.
AVE
PRINCE ST.
INDUSTRIAL
VENTURI
ITT HAMMEL DAHL CONOFLOW
ROAD
BLVD
DRYDEN
AVENUE
POST
AVE
TENNYSON
BYRON
MILTON
HOLMES
IRVING
ST
POWER
BOSTON
WARWICK
BUREN
ST
ATLANTIC
JEFFERSON
VAN



WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND

SPF-NATURAL CONDITIONS

(MOUTH TO RIVER MILE 1.6)

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

PLATE II-7

CHAPTER III

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FORMULATION OF PRELIMINARY PLANS

TABLES

PLATES

FIGURE

OBLIQUE PICTORALS

FORMULATION OF PRELIMINARY PLANS

Principal water resource problems within the basin show the need for flood management measures, phased development of public water supplies and water quality improvement measures. Alternative solutions for satisfying flood control needs are evaluated in this section. Water supply and water quality improvement measures have been the subject of previous and ongoing studies by the Rhode Island Water Resources Board, Rhode Island Statewide Planning Program, and this office.

MANAGEMENT MEASURES

All potential regulatory and corrective measures for meeting the flood protection needs of the basin were initially identified and briefly appraised. Implausible measures were rejected. A No Action Program (one entailing no Corps of Engineers participation) was considered throughout the plan formulation process. It assumes that all communities would control growth within their flood plains, at least to meet the minimum requirements of the ongoing National Flood Insurance Program (NFIP). The NFIP provides a Federal subsidy to private insurers so that flood-prone properties may be eligible for flood insurance ($90,000 limit for single family residence and contents, and $400,000 limit for nonresidential property and contents).

Presently most basin communities have initiated participation in the NFIP which should lead to local programs for controlling growth within the flood plains. Communities declining to participate become ineligible for any Federal expenditures within a flood-prone development, and property owners for properties within the flood plains would be unable to obtain financing from Federally insured lending institutions.

Regulatory measures discourage the use and development of the flood plains, thus lessening the threat of flood damage and possible loss of life.

Flood plain regulations help avoid repetition of past building errors by preventing additional construction on already developed flood plains. Communities may adopt more stringent regulations than those required by the National Flood Insurance Program. Such restrictions require the enactment of ordinances to implement and enforce land use planning programs involving the delineation of flood hazard areas.

Encroachment lines drawn on the map on each side of a watercourse show the lateral limits within which development must be restricted in order to preserve the flood carrying capacity of the stream and

prevent further growth in the flood plain. Figure III-1 is a schematic drawing of this concept. The central portion, or floodway, consists of the stream channel and that portion of the adjoining flood plain required to pass a 100-year flood. No construction or filling should be allowed there, although parking lots, recreation, agriculture, and other nonstructural uses may be permitted, provided that the free flowing state of the floodway is not impaired.

The floodway fringe is the remainder of the 100-year flood plain. Limited encroachment or filling may be allowed here, providing it does not cause the water level of the 100-year flood to rise more than one foot (or less if so established by State or local regulations). Any construction here must be flood-proofed to the 100-year flood level.

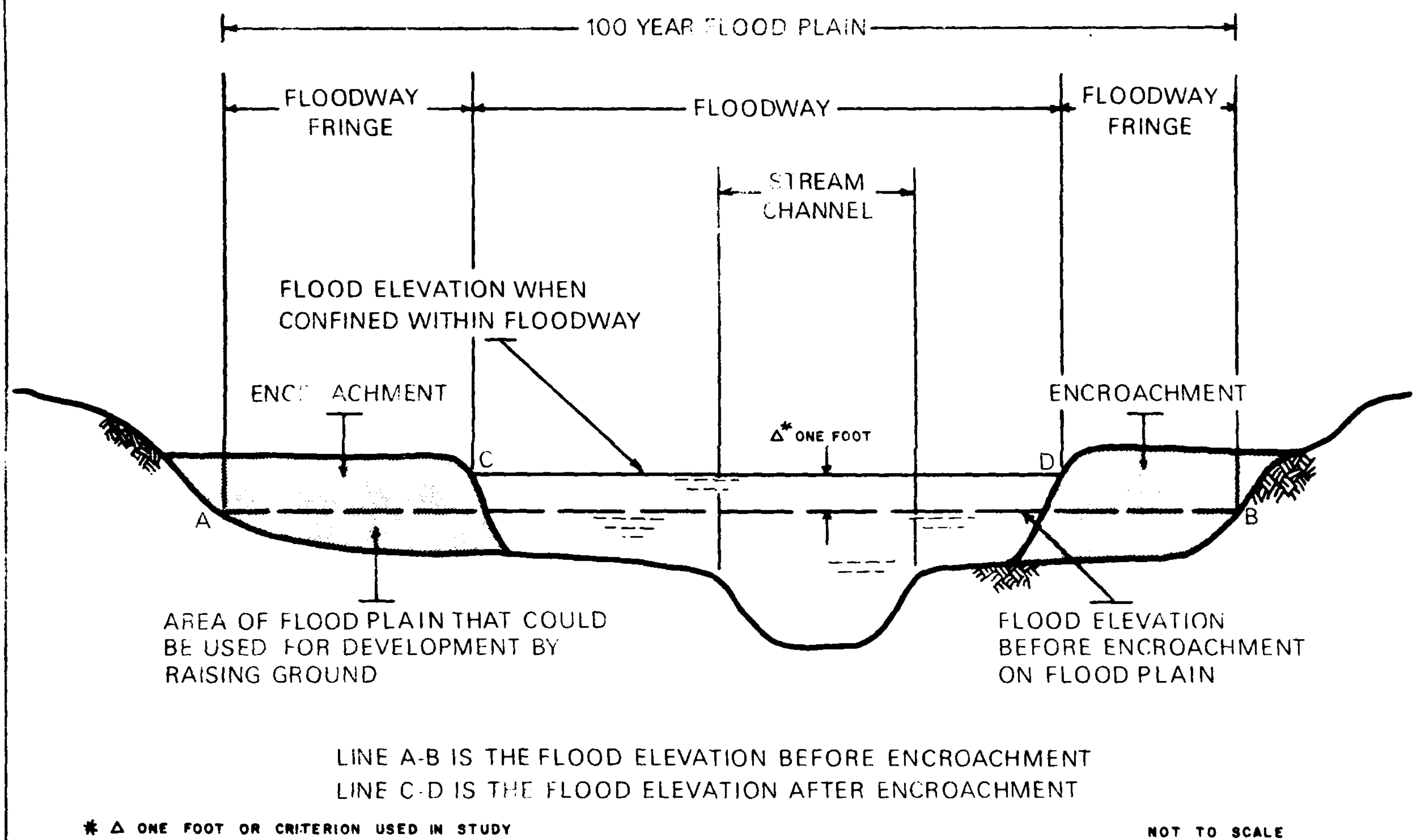
Zoning is the legal measure used to enforce land use and development restrictions in the flood plain by governmental agencies. It insures the safekeeping of this property for the health, welfare, and safety of the public.

Subdivision regulations are used by local governments to control construction in undeveloped flood plains by specifying minimum elevations, drainage, location restrictions, and other conditions to prohibit encroachment in flood hazard areas.

Land use programs for conservation, scenic, and flood control purposes may include land use restrictions, purchase of land use rights, lowering of tax assessments, and other measures to meet public objectives -- such as preventing development in flood plains -- while allowing continued private ownership of the land.

Other regulatory measures to lessen the threat of flood losses include:

Building codes which specify minimum standards of design, construction, and quality of materials to reduce potential flood damages in structures whose location in flood hazard areas cannot be prevented. Such restrictions could prevent buildings from floating off their foundations, establish minimum basement and first floor elevations consistent with potential flood occurrences, prohibit basements that would be subject to shallow flooding, require reinforcement to withstand water pressure or high velocity flow, restrict the use of materials which deteriorate rapidly in the presence of water, and prohibit equipment that might be hazardous to life when submerged.



DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

FLOODWAY SCHEMATIC

Fig. III-1

Urban redevelopment presents opportunities to remove developments from the flood plain and make sure that new construction in the flood plain is designed to withstand flooding.

Tax adjustments on land dedicated to open space uses, such as agriculture, recreation, and conservation helps to preserve undeveloped flood plains.

Warning signs of previous high water levels warn prospective buyers that a flood hazard exists. Required certification by sellers that the property is reasonably flood free is even more effective.

Health and fire regulations should include contingency plans for temporary evacuation of people, property, and livestock from low lying areas, prevention of disease should water supplies become polluted or sanitation facilities inoperative, accessibility to fire fighting equipment, and emergency fire reporting systems.

Flood forecasting can reduce property losses significantly and save lives. Information from the Federal government's extensive weather forecasting system should be effectively disseminated at the local level.

Structural components are often the most practical way to control floods and reduce damage in heavily urbanized flood-prone areas where regulatory measures would be too expensive or environmentally or socially undesirable.

Land treatment measures reduce erosion, reduce runoff, and lessen the damaging movement of sediments to streams and flood plains. Vegetative and mechanical measures developed for conservation practices -- contour farming, cover cropping, terracing, critical area planting, and the like -- are also effective on urban lands undergoing development.

Reservoirs for impounding uncontrolled flood waters provide a high level of protection to downstream communities, while satisfying other needs, such as water supply and public recreation.

Walls and dikes confine flood flows to the channel or floodway and provide protection to local high-risk areas.

Reservoir management programs provide for the addition of flood control storage in existing reservoirs, with controlled release after the flood danger passes.

Hurricane barriers use walls, dikes, gates, and pumping facilities to prevent high tides from intruding and raising flood heights along the lower main stem.

Stream improvements can increase the flood carrying capacity of floodways by eliminating abrupt turns, widening and deepening channels, improving areas at bridges and culverts, alleviating erosion problems, and removing shoals, sandbars, islands, overhanging and uprooted trees, and accumulated debris. Diversion of flood flows to bypass heavily congested flood-prone areas offer great protection while minimizing environmental and social impacts.

Flood proofing or relocation render buildings and contents less vulnerable to flood damage. They include:

1. Permanent measures such as waterproofing, installation of drain systems and pumps, anchoring and reinforcing walls and floors, use of water resistent materials, raising the elevation of structures, terminating entering utilities, protecting immovable equipment, bricking windows, relocating entrances, and drawing up plans for emergency protection measures.

2. Contingency measures such as manually closed sewer valves and removable bulkheads for windows, doors and vents.

3. Emergency measures such as sandbagging, pumping and removal of contents to high elevations.

4. Permanent evacuation of developed areas by removing structures and relocating people, so that flood-prone lands could be returned to natural habitat or used for agriculture, parks and recreation. Temporary evacuation is also effective when used in conjunction with a reliable flood warning system.

Those measures which should receive more detailed consideration for inclusion in the plan were screened. Advanced level quantitative and economic analysis was made of nonstructural (flood proofing, relocation) as well as structural (dikes, diversions, floodwalls, channel modification) measures. Also, consideration was given to future action measures such as reservoir management, the construction of Big River Reservoir, and land treatment measures. A reconnaissance report, completed in December 1971, discussed preliminary screening solutions that were considered to date.

Combinations of the alternative measures were evaluated and screened next. Various plans, all providing comparable levels of flood protection, were analyzed in addition to the no action plan.

Significant beneficial and adverse impacts of each plan were evaluated in terms of national economic development, environmental quality, social well-being, and regional development. The best alternative plan was selected.

The selected plan was formulated for an appropriate scale of development. It consists of a downstream local protection project, in an area where homes are to be relocated, and an upstream multi-purpose reservoir which involves flood control. Regulatory measures are also part of the plan.

PLAN FORMULATION RATIONALE

In evaluating possible alternative solutions for the basin's flood management needs, technical, economic, and social criteria, including consideration of all beneficial and detrimental effects on the area's environment, were used. Although it was not possible to evaluate all possible alternatives to the same degree of technical detail, supplemental planning criteria for all possible alternatives involved acceptability, completeness, effectiveness, equity, irreversible effects, and ease of maintenance and operation. Socio-economic data used in evaluating costs and benefits were derived from Corps investigations and other published data of State and Federal agencies. Hydrologic and hydraulic data were obtained from Corps studies. Environmental impact information was obtained from Corps studies and water quality sampling by the Federal Environmental Protection Agency.

ECONOMIC CRITERIA

1. Tangible benefits must exceed project economic costs.
2. Intangible benefits, such as protection of lives and property, may cause the scope of development to be greater than would otherwise be required to provide maximum nec tangible benefits.
3. The recommended plan must not physically displace or economically preclude from development any more economical means for accomplishing the same purpose.

TECHNICAL CRITERIA

Technical criteria adopted from engineering manuals, regulations and other sources require that the plan be feasible to implement, complete with no additional future improvements, and insure against significant worsening of any flood conditions. Alternative measures

were formulated in accordance with regulations stipulating that the standard project flood is an appropriate level of protection for high dikes and floodwalls in urban areas.

ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Requirements of the National Environmental Policy Act of 1969 include:

1. Analysis of the environmental impact of any proposed action.
2. Identification of adverse environmental effects which could be avoided in project implementation.
3. Evaluation of alternatives to the proposed action.
4. Determination of the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity.
5. Accounting of any irreversible and irretrievable commitments of natural resources and biological systems which would be involved in the project.

Requirements of the Principles and Standards of the Water Resources Council include:

1. Management, protection, enhancement, or creation of areas of natural beauty and human enjoyment.
2. Management, preservation, or enhancement of especially valuable or outstanding archeological, historical, biological, and geological resources and ecological systems.
3. Enhancement of quality aspects of water, land, and air, while recognizing and planning for the need to harmonize conservation of the resources with the land use objectives of productivity for economic use and development.
4. Development and use objectives which minimize or preclude the possibility of undesirable and irreversible changes in the natural environment.

Considerations mandated by Section 122 of the 1970 River and Harbor Act include:

1. Effects of air quality, noise levels, and water pollution.
2. Destruction or disruption of manmade and natural resources, aesthetic values, community cohesion, and the availability of public facilities and services.

3. Adverse employment effects and tax and property value losses.
4. Injurious displacement of people and businesses.
5. Disruption of desirable community and regional growth.
6. Public acceptance of proposed improvements and their ability and willingness to meet local cooperation requirements.

Other social well-being factors include:

1. Possible loss of life and hazards to the health and safety of the people with and without project conditions.
2. Preservation of pleasing aesthetic values and other desirable environmental effects, such as pleasing landscapes.

The Environmental Impact Statement included as a chapter of this main report, provides greater in-depth coverages of these considerations.

PLANS OF OTHERS

Construction of the Big River Reservoir was proposed in 1952 for the Rhode Island Water Resources Board by a consultant. In 1957 a report was made to the Water Resource's Board by another consultant, which reviewed additional data and made further recommendations regarding the Big River Reservoir. Metcalf and Eddy also prepared a report in June 1967 updating these two previous reports to reflect the drought conditions in the early 1960's. This project was therefore in a planning stage long before January of 1978 when the Governor of Rhode Island asked that the Corps of Engineers study this proposal. The recommended plan assumes that the Big River Reservoir will be built and maintained by Federal interests. Plans prior to this time regarded the reservoir as a future action measure to be implemented by non-Federal interests as a means of supplementing the flood protection provided by other single action measures.

ANALYSIS OF PLANS CONSIDERED IN PRELIMINARY PLANNING

INITIAL SCREENING

All regulatory and corrective measures, as well as a No Action plan, were evaluated with engineering judgment and brief study for application in each of the 16 zones of the watershed. Each measure was judged on its own merits and those not considered adequate, realistic, practical engineering solutions, or measures socially or environmentally unacceptable or economically unjustified, were

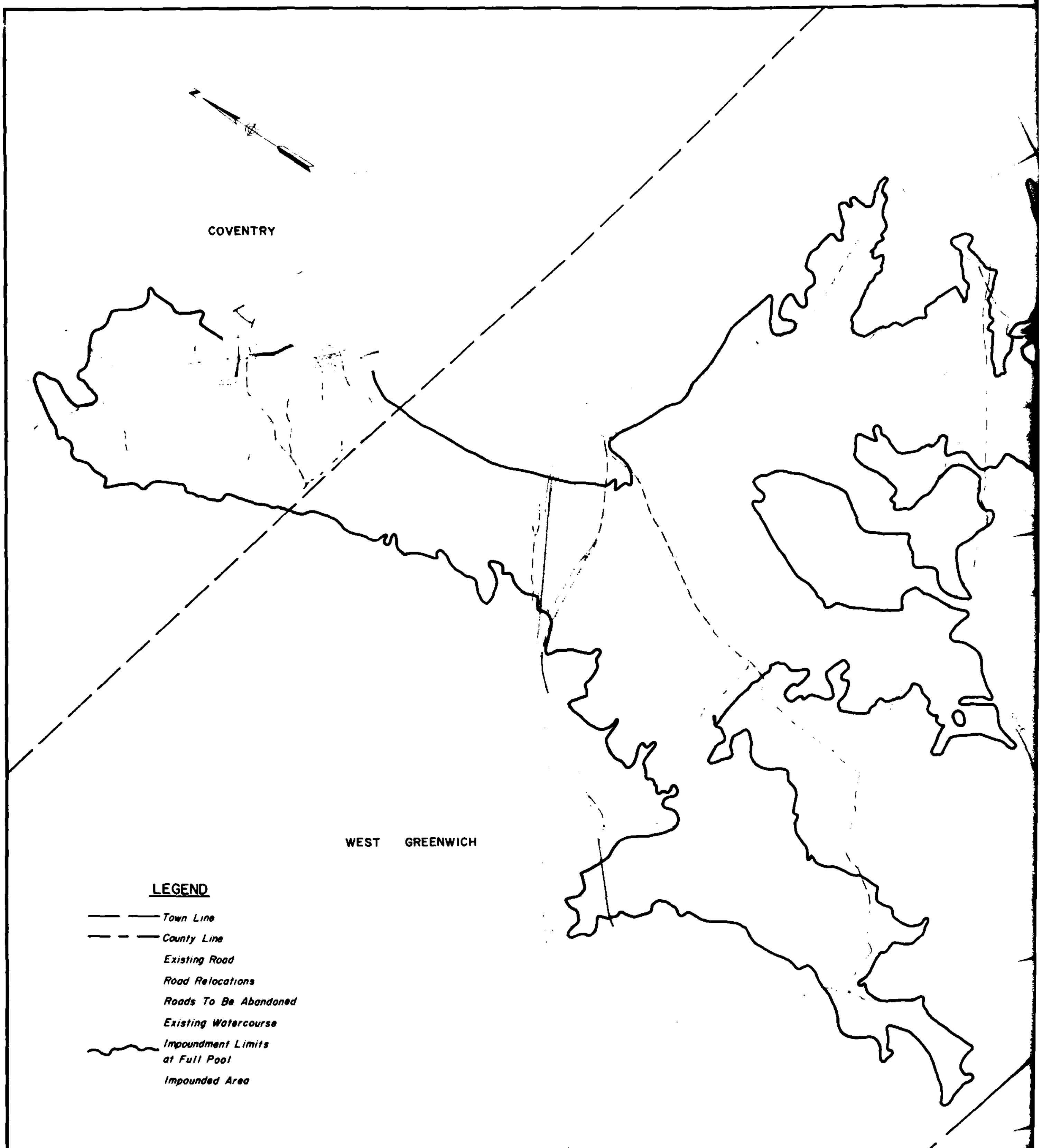
eliminated. Both the No Action program and all regulatory measures were determined to be applicable to all 16 damage zones, for preventing or minimizing flood losses to future flood plain development, and both programs were therefore reserved for further evaluation.

Land treatment measures for Zone 2 were held for future evaluation in conjunction with potential construction of the Big River Reservoir, in view of ongoing gravel operations within the area and the need for soil erosion prevention measures during reservoir construction. In other zones, significant erosion and sedimentation problems were deemed nonexistent, not subject to correction by vegetative or slope protection measures. Where substantial loss of cover has been caused by the introduction of an intricate interstate highway system, existing unstable embankments will stabilize themselves, thus resulting in less critical erosion. Assistance in land treatment measures in certain zones is available, under existing authority, through the Soil Conservation Service, U.S. Department of Agriculture.

Reservoirs at numerous sites within the study area were investigated. Most of the sites investigated were found to be too small to provide economically justified protection or were not acceptable because of engineering, social and environmental constraints.

Twelve reservoir sites were investigated further. Seven were within the Pocasset River watershed and one on a tributary of the Meshanticut Brook. Four impoundments were on the North and South Branches, two involving modification of the existing Flat River and Scituate Reservoirs. Of the twelve, only one potential project, the Big River Reservoir, could provide substantial flood reduction benefits. Plate III-1 shows site location of this potential reservoir project.

Modification of Scituate Reservoir, which is presently used mainly for water supply purposes (but also has a small hydropower unit), was found to be economically unjustified. Although this reservoir has played a substantial role in reducing flood stages and resultant damage in the past, it is managed exclusively to optimize its water supply capabilities. Its flood control capabilities are, therefore, contingent upon its being drawn down due to high water consumption and low flow conditions. The need to meet future imposed demands upon the water supply system will require that it continue to be operated solely for water supply purposes. To utilize Scituate Reservoir for flood control purposes would require raising the existing structure an additional ten feet or providing a sub-



COVENTRY
WEST GREENWICH
LEGEND
Town Line
County Line
Existing Road
Road Relocations
Roads To Be Abandoned
Existing Watercourse
Impoundment Limits at Full Pool
Impounded Area

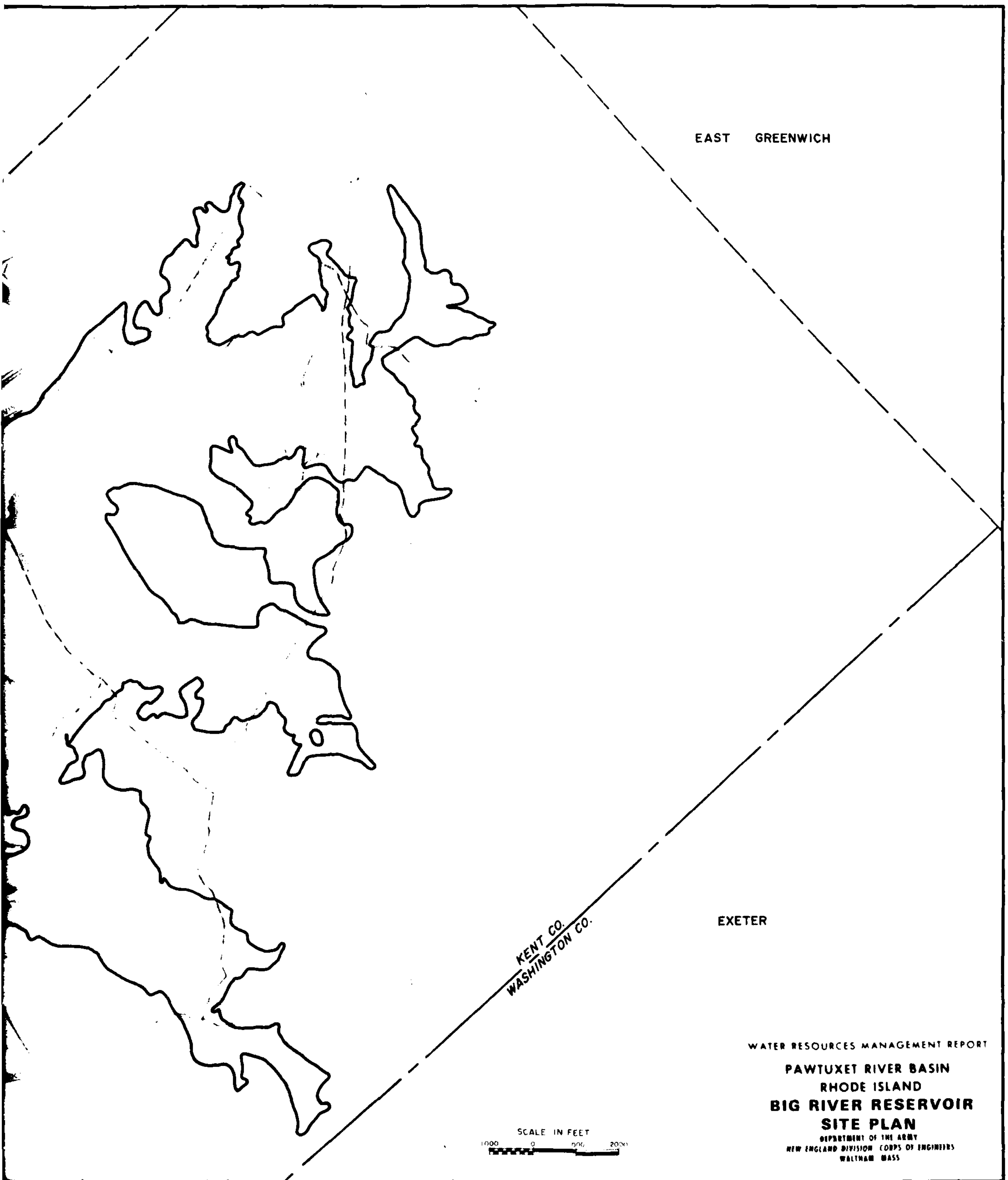

EAST GREENWICH
EXETER
KENT CO.
WASHINGTON CO.
SCALE IN FEET
WATER RESOURCES MANAGEMENT REPORT
PAWTUXET RIVER BASIN
RHODE ISLAND
BIG RIVER RESERVOIR
SITE PLAN
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION CORPS OF ENGINEERS
WALTHAM MASS

PLATE III-1

impoundment within the reservoir. The costs of either project would far exceed the benefits to be derived by downstream communities in flood damage reduction.

Walls and dikes are an effective means for providing flood protection to high risk flood-prone areas where numerous structures susceptible to high flood losses are located. Seven zones in the basin meet these high risk conditions, and wall and dike measures were retained for further evaluation in these zones.

Reservoir management programs entail lowering the levels of existing reservoirs to reduce peak flood discharges. With the exception of Scituate and Flat River Reservoirs, further investigation of the other, smaller reservoirs in the basin was deemed impractical because of the small storage capacities involved.

Hurricane barriers to eliminate tidal flooding under adverse storm conditions were considered at both the entrance to Pawtuxet Cove and at the head of the cove where the river discharges. Excessive costs and adverse social and environmental impacts eliminated these projects from further investigation.

The barrier at the river mouth would involve total reconstruction of Pawtuxet Dam, huge pumping facilities, extensive river widening, relocation of numerous industrial, commercial and residential structures, and modification of six bridges and several local roads. These costs would far exceed benefits.

The other scheme, at the entrance to Pawtuxet Cove, would require even more construction and relocation and larger pump installations whose costs would far exceed benefits.

Stream improvements to correct long-neglected channel conditions which have resulted in alarming deterioration of the hydraulic efficiency of some of the basin's major streams, were considered for the following major elements:

Removal of dams, particularly those numerous small dams within the basin originally intended for power generation and are now neglected and obsolete, was considered as a means of lowering flood stages in their vicinity. It was estimated, for example, that the flood stage under Standard Project Flood conditions could be reduced by two feet over several thousand feet of impoundment upstream of the Pontiac Dam were that dam to be removed in accordance with local wishes. However, related costs of the project would exceed accrued benefits, and subsequent analysis was deemed unwarranted.

Removal of Pawtuxet Dam at the river mouth would result in insignificant upstream flood stage reductions which would be negated

by the resulting counteraction of incoming high flood tides. Removal of other, obsolete dams, while beneficial, would create erosion problems downstream that would exceed the benefits gained.

Diversion of floodflows to bypass heavy damage zones within the basin or transfer floodwaters outside of the basin were both considered. Numerous intrabasin schemes were evaluated but none appeared viable and further evaluation was deemed unwarranted.

An interbasin transfer of floodflows appeared viable for Zones 3 or 4, as diversion could be made upstream of main stem damage centers and provide substantial flood relief to flood prone areas in three communities with minimal social and environmental disruption. Furthermore, the diversion could be made to Apponaug Cove, a tidal arm of Greenwich Bay, where the addition of riverine floodwaters would not significantly increase tidewater levels at high tide conditions. A relatively high head could be developed, thereby reducing conveyance size and project costs. This interbasin transfer was therefore reserved for further evaluation.

An alternate diversion at Zone 3 was rejected due to longer diversion length and the necessity of a new control dam being constructed, which would result in more controversial social and environmental involvement.

Channel modification to improve streamflow by channel widening, deepening or realignment was rejected in several tributary zones because existing minimal damage would not be eliminated by channel modification. Channel modification in all other zones was found to be economically or hydraulically impractical because of excessive depths of flooding encountered or existing nearly flat stream gradients. Further consideration was therefore considered unwarranted, with the single exception of the need for channel modification should a potential local protection project, such as a wall or dike, encroach significantly on the existing cross-sectional area of a stream.

Flood proofing and relocation was found to warrant further evaluation in all zones except 1, 2, 3, 4A and 7A, where the flood problems were determined to be minimal.

Eighty-four percent of the corrective measures proposed failed to meet the minimum acceptable plan requirements in the screening process and were therefore eliminated. Twenty-three possible solutions were deemed worthy of more detailed analysis. As previously noted, all regulatory measures and the No Action plan were also retained for further analysis.

ADVANCED SCREENING

Those measures which passed the initial screening were further analyzed to see if they could provide an adequate degree of protection in major damage areas while meeting the established criteria.

The first element of this evaluation process consisted of a nonstructural program of regulatory and corrective flood proofing measures, that were analyzed in depth in accordance with the desires of local interests. Following that a structural program was evaluated, followed by consideration of future action measures.

CORRECTIVE NONSTRUCTURAL PROGRAM

Flood proofing entailed a major component of this program. It involves techniques to make existing buildings and their contents less vulnerable to flood damages. The following criteria were applied to this program:

a. For initial analysis, unreinforced concrete walls were considered capable of withstanding the hydrostatic pressures of a 3 foot head differential between water surfaces on either side of the wall without collapsing.

b. Wood frame structures cannot be floodproofed above the sill.

c. Structurally sound buildings can be raised only three feet because of esthetics.

d. Where depths of water for the design condition exceed the heights of a and c above, relocation would be necessary.

e. Ring wall enclosures were only considered for the purpose of tying a building's wall into high ground.

f. At the design flood conditions, all structures that could potentially be inundated were raised and/or floodproofed if necessary, even though only nuisance basement flooding would occur.

g. The drag line effect (the difference in water levels due to passage of flows through soil) was not considered in this phase of analysis. There are too many variables such as soil permeability, drainage nets or patterns, condition of the concrete slab and wall, the tightness of any joints or seams etc., to accurately predict the true effects.

h. Uplift pressures were not considered.

To determine the viability of flood proofing in zones 3-8, costs were developed for all structures for both 100-year and Standard Project Floods. Results are shown by community and use category in Table III-1 and by category of use of structure in Table III-2. For protection against a Standard Project Flood, about 616 existing structures -- 33 percent of those located in the SPF area -- would require relocation. Eighty-three of these are commercial or industrial establishments employing more than 5,700 people. For a 100-year flood, about 26 structures, of which 14 are commercial or industrial employing about 2,500 people, would need to be relocated.

The cost figures indicate that flood proofing alone, without other flood protection measures in combination, would not meet the benefit-cost criterion and would be economically, socially, and environmentally prohibitive.

TABLE III-1

FLOODPROOFING - NATURAL CONDITIONS
TOTAL COST AND AFFECTED OWNERSHIPS
(By Community & Category)

COMMUNITY/ CATEGORY	100-YEAR FLOOD		STANDARD PROJECT FLOOD	
	#	$1,000	#	$1,000
WARWICK				
Commercial	21	15,000	44	104,600
Industrial	13	17,090	19	40,300
Residential	146	1,470	570	17,050
Public	2	70	2	1,290
Schools	0	0	0	0
Others	3	60	4	2,120
TOTAL WARWICK	185	$33,690	639	$165,360
CRANSTON				
Commercial	11	1,130	27	8,300
Industrial	6	18,810	16	79,200
Residential	206	1,200	1,083	23,930
Public	2	40	8	1,710
Schools	1	50	2	1,180
Others	2	220	5	4,540
TOTAL CRANSTON	228	$21,450	1,141	$118,860
WEST WARWICK				
Commercial	10	890	11	2,230
Industrial	4	370	5	1,100
Residential	41	980	53	3,040
Public	1	50	1	490
Schools	1	40	3	2,160
Others	1	10	3	850
TOTAL WEST WARWICK	58	$2,340	76	$9,870
TOTAL	471	$57,480	1,856	$294,090

TABLE III-2

NONSTRUCTURAL COSTS - NATURAL CONDITIONS
TOTAL COSTS AND AFFECTED OWNERSHIPS
(By Category)

1978 CONDITIONS AND PRICE LEVELS
ALL VALUES x $1000

CATEGORY	100-YEAR FLOOD		STANDARD PROJECT FLOOD	
	#	VALUE	#	VALUE
Commercial	42	17,020	82	115,130
Industrial	23	36,280	40	120,670
Residential	393	3,660	1,706	44,020
Public	5	150	11	3,490
Schools	2	80	5	3,350
Others	6	290	12	7,510
TOTAL	471	$57,480	1,856	$294,170
Amortized over a 50 year life 6-5/8 = .069078		$3,971		$20,321
Annual Benefits		380		760*
Approx. Benefits to Relocated Structures		90		820
B/C Ratio		.10		.04

*Excludes benefits to relocated structures, (equal to approximately $88,000 and $820,000 for 100 year and SPF flood respectively), non-physical losses, exterior losses, roads and utilities.

In other zones, preliminary evaluation indicated that costs of floodproofing alone would far exceed benefits.

Therefore, floodproofing as an independently used measure was rejected as not satisfying benefit-cost criteria. It was, however, retained for further consideration in combination with other measures.

STRUCTURAL PROGRAM

Two types of structural flood management programs were considered to protect heavily urbanized areas in the flood plain along the lower end of the main stem.

Two systems of dikes, walls, and channel modification were evaluated, one to protect against the Standard Project Flood, the other against the lower level of the 100-year flood. These are designated respectively as Alternate A and A-1.

Alternate A would require 12 individual local protection projects in three communities, at a total cost of $60 million in 1978 dollars. Plate III-2 shows this scheme. Analysis showed that the plan as a total unit would not be economically justified, although local projects at Warwick Avenue, Elmwood Avenue, and the Bulova Complex warranted further investigation.

Alternate A-1 entailed the same projects but at a lower level of flood protection. Once again, the total plan was not found to be economically justified, but the local projects at Warwick Avenue, Elmwood Avenue and the Bulova Complex were justified as a system. Alternate A-1 would cost a total of $29.4 million. Plate III-3 presents this project.

Both Alternate Plans A and A-1 were rejected, but economically justified local projects were retained for further evaluation. Plate III-4 depicts the Warwick Avenue Local Protection Works and III-5 shows the Elmwood Avenue area.

The Bulova local protection project was evaluated in greater economic and engineering detail. Based upon the availability of more refined engineering data, it was determined that two significant modifications of the preliminary project considered in the advanced screening would be required. Relocation of a portion of a warehouse would be required as a measure to provide the necessary land area for dike construction, or the use of concrete floodwalls would be required for a portion of the previously considered dike protection plan. The second modification would require major relocation of a brook. Because of the additional costs for providing these essential

modifications, the project lost its previous marginal justification and was withdrawn from further consideration. The estimated cost for this project based on the more detailed engineering and design criteria is 1.92 million dollars in 1977 dollars, while the benefits also would rise due to inflation (about 30 percent). Further Federal involvement for the Bulova project is unwarranted.

Two alternate diversions of floodwaters were also evaluated.

Pontiac Diversion project considered four different alignments of an underground tunnel and/or open chann[illegible] to divert flood waters from the main stem above Pontiac Dam to the head of Apponaug Cove.

Alignments A and B, each about 10,000 feet long, would require extensive land taking and require relocation of at least 10 homes. Both were eliminated from further consideration due to highly detrimental environmental effects, adverse social impacts, and substantial opposition by local interests.

Alignment C would pass through Gorton Pond, thus requiring a net constructed length of only 6,600 feet of open channel. An adverse environmental impact would be created by diverting the Class C waters of the Pawtuxet River to the Class B waters of Gorton Pond, a local recreational water body, thus eliminating this alignment from further consideration.

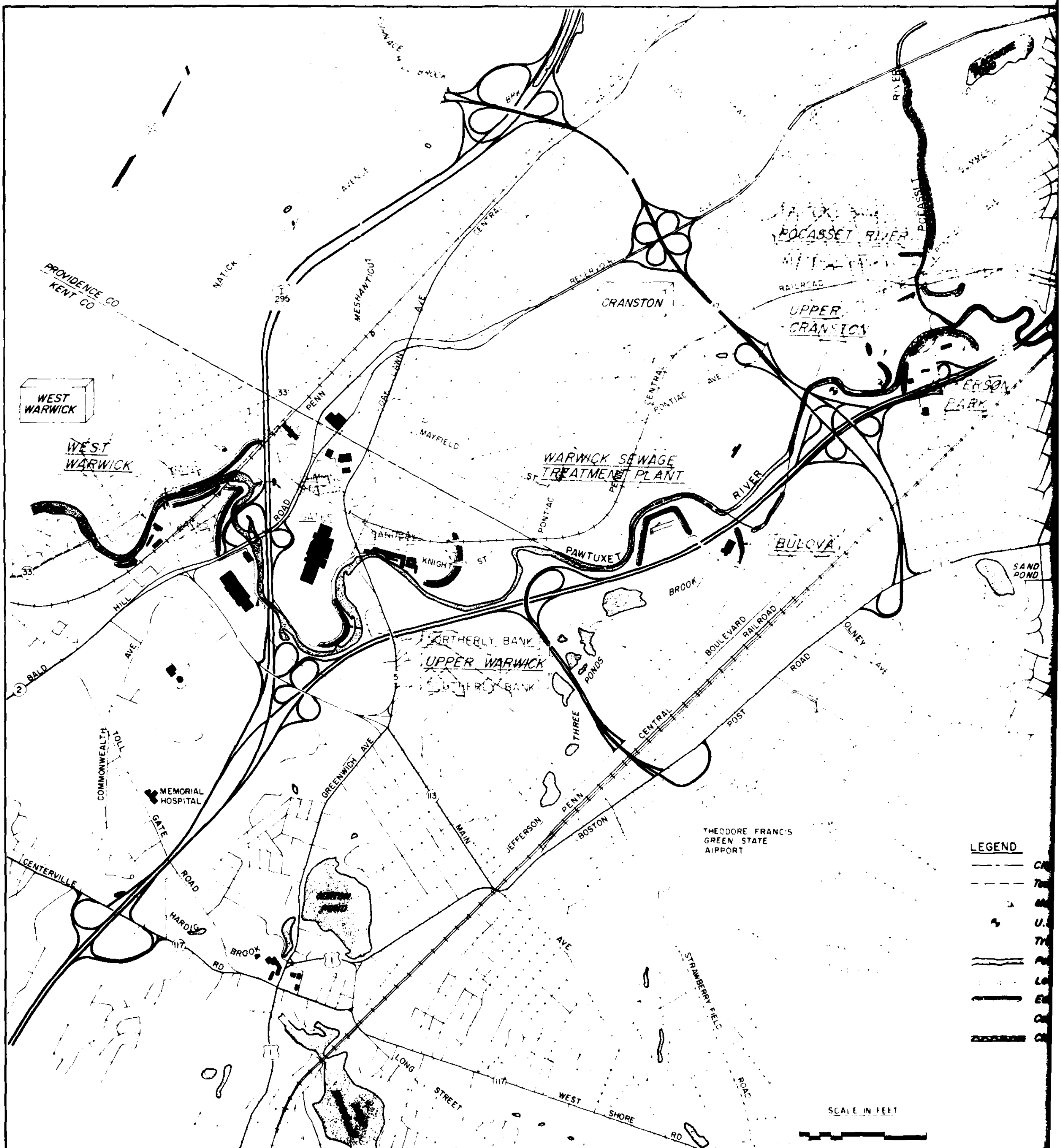
Alignment D, an 8,000-foot tunnel through bedrock is considered the most suitable. However, its cost -- including extensive channel modification and a massive pumping station -- would be more than $70 million. This would far exceed benefits, so this alignment was also rejected.

Natick Diversion, with its intake 10,000 feet further upstream just below the Natick Dam, was the other alternative considered. It was found to provide a high degree of protection to existing and future downstream development at a lower cost and was eonomically justified. Therefore, this diversion was reserved for further evaluation. These plans are shown on Plates III-6 and III-7.

FUTURE ACTION

Three future action programs to be implemented by local interests could strengthen the flood management program for the Pawtuxet River basin: reservoir construction, reservoir management and land treatment measures.

1. Construction by local interests of the proposed and recommended Big River Reservoir as a potential water supply for metropolitan Providence could provide significant downstream flood



PROVIDENCE CO
KENT CO
WEST WARWICK
WEST WARWICK
NATICK
MESHANTICUT
CENTRAL
PENN
AVE
ROAD
CRANSTON
POCASSET RIVER
UPPER CRANSTON
RAILROAD
POCASSET
RIVER
MAYFIELD
WARWICK SEWAGE TREATMENT PLANT
PONTIAC
AVE
KNIGHT ST
PAWTUXET
RIVER
BULOVA
BROOK
SAND POND
NORTHERLY BANK
UPPER WARWICK
BALD HILL
AVE
COMMONWEALTH
TOLL GATE ROAD
MEMORIAL HOSPITAL
GREENWICH AVE
MAIN
THREE PONDS
BOULEVARD
RAILROAD
CENTRAL
POST ROAD
OLNEY AVE
JEFFERSON
PENN
BOSTON
THEODORE FRANCIS GREEN STATE AIRPORT
CENTERVILLE
HARDIG
BROOK
RD
AVE
STRAWBERRY FIELD ROAD
LONG STREET
WEST SHORE RD
LEGEND
SCALE IN FEET

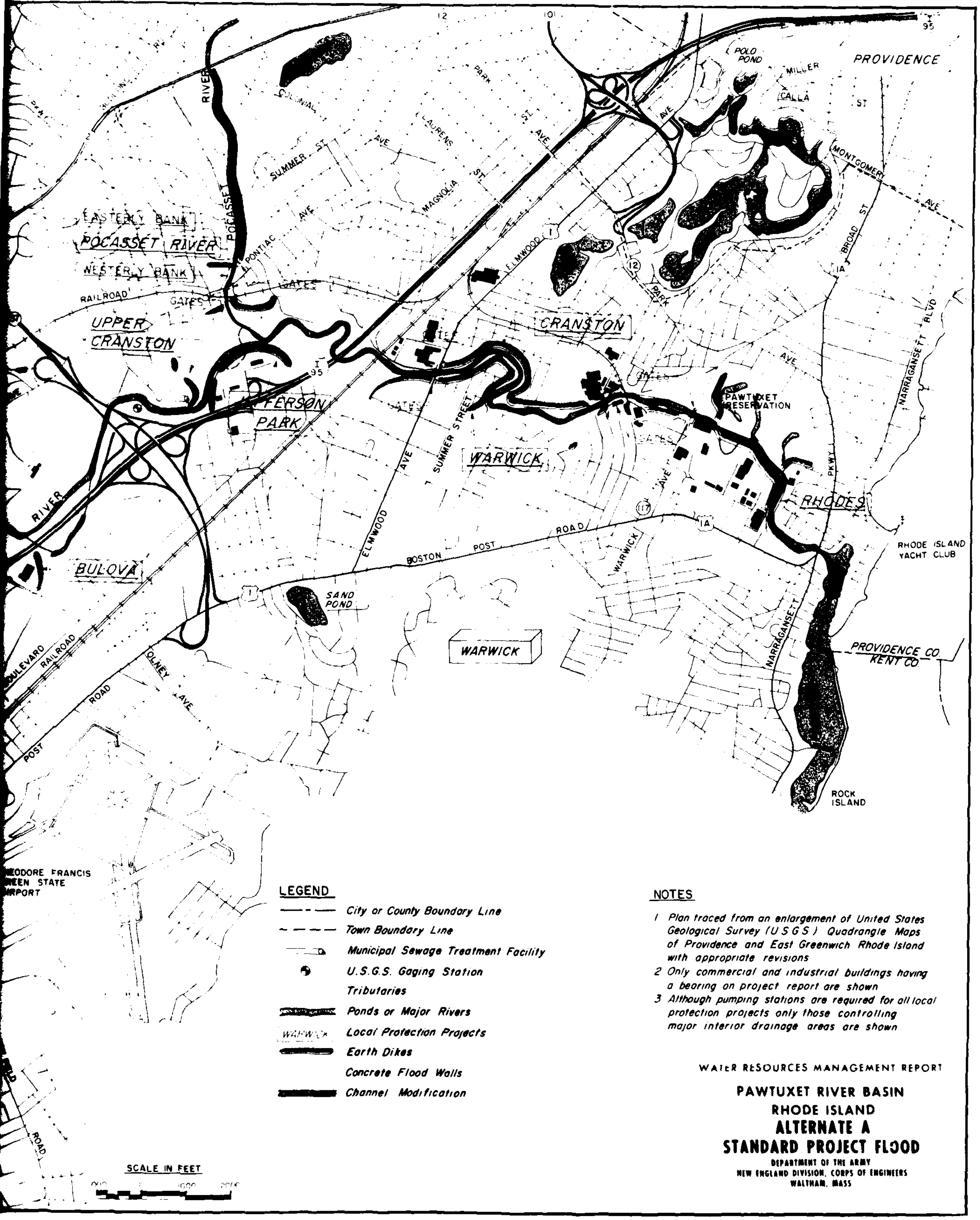
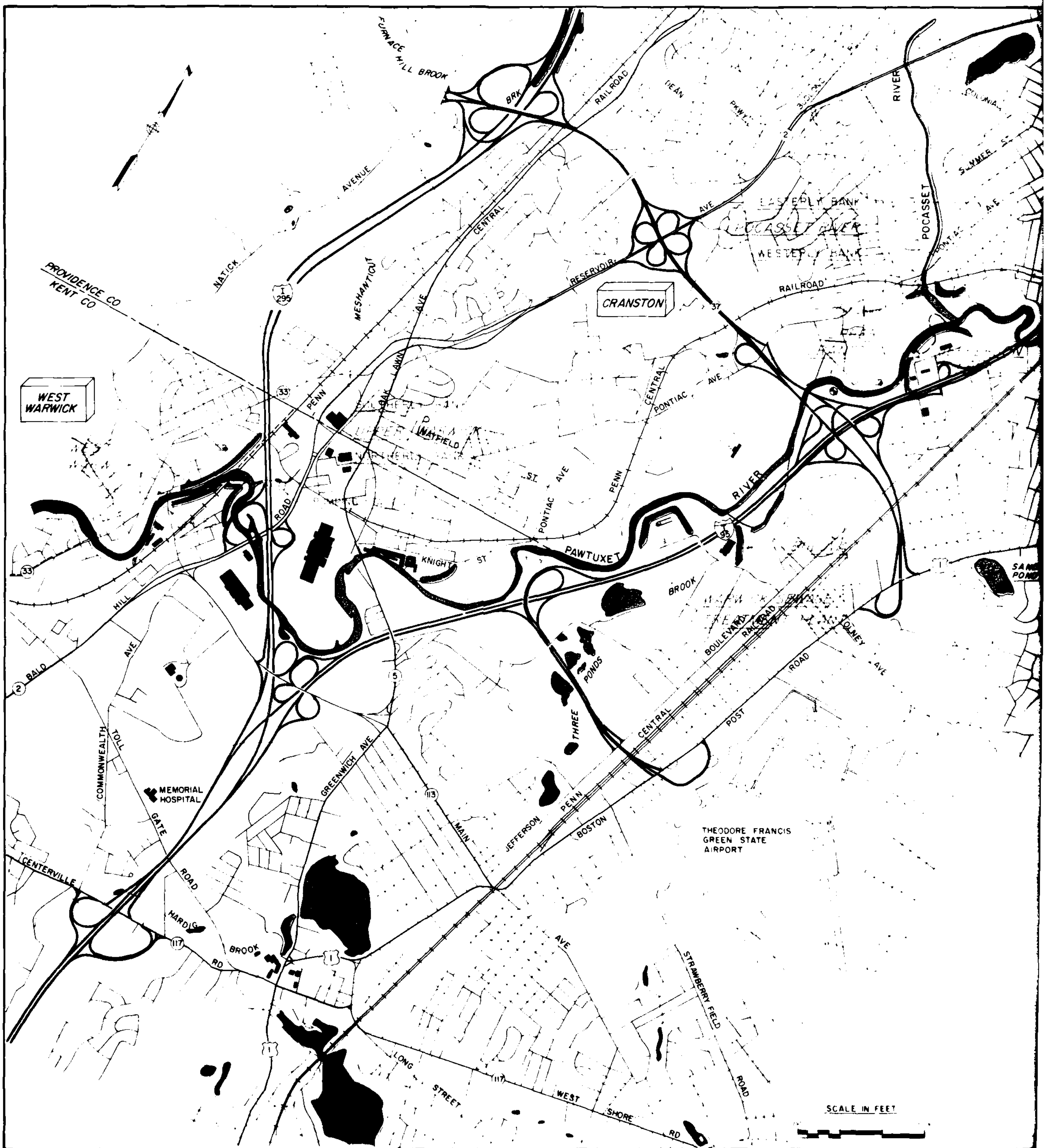
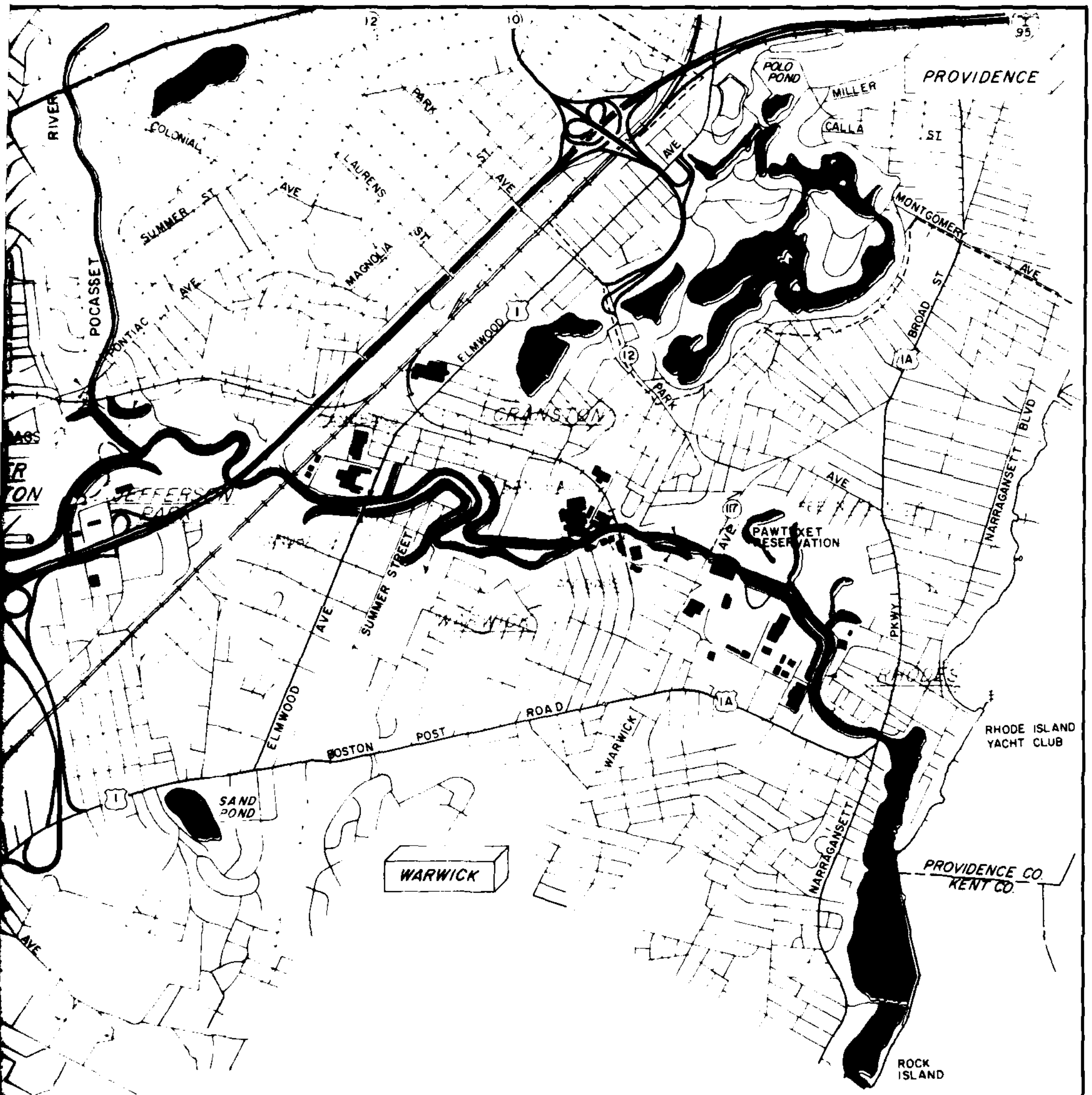

PROVIDENCE
POLO POND
MILLER
CALLA
ST
MONTGOMERY
AVE
BROAD ST
1A
PARK
12
101
95
COLONIAL
LAURENS
ST
AVE
SUMMER ST
MAGNOLIA
PONTIAC
ELMWOOD
EASTERLY BANK
POCASSET RIVER
WESTERLY BANK
RIVER
POCASSET
RAILROAD
GATES
UPPER CRANSTON
CRANSTON
JEFFERSON PARK
PAWTUXET RESERVATION
NARRAGANSETT BLVD
SUMMER STREET
ELMWOOD AVE
WARWICK
RHODES
RHODE ISLAND YACHT CLUB
BOSTON POST ROAD
117
RIVER
BULOVA
SAND POND
WARWICK
NARRAGANSETT
PKWY
PROVIDENCE CO.
KENT CO.
ROCK ISLAND
BOULEVARD
RAILROAD
OLNEY AVE
POST ROAD
THEODORE FRANCIS GREEN STATE AIRPORT
ROAD
SCALE IN FEET
LEGEND
City or County Boundary Line
Town Boundary Line
Municipal Sewage Treatment Facility
U.S.G.S. Gaging Station
Tributaries
Ponds or Major Rivers
Local Protection Projects
Earth Dikes
Concrete Flood Walls
Channel Modification
NOTES
1 Plan traced from an enlargement of United States Geological Survey (U S G S) Quadrangle Maps of Providence and East Greenwich Rhode Island with appropriate revisions
2 Only commercial and industrial buildings having a bearing on project report are shown
3 Although pumping stations are required for all local protection projects only those controlling major interior drainage areas are shown
WATER RESOURCES MANAGEMENT REPORT
PAWTUXET RIVER BASIN
RHODE ISLAND
ALTERNATE A
STANDARD PROJECT FLOOD
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

PLATE III-2


WEST WARWICK
CRANSTON
PROVIDENCE CO
KENT CO
FURNACE HILL BROOK
NATICK AVENUE
MESHANTICUT
CENTRAL
RAILROAD
DEAN PKWY
RESERVOIR AVE
RIVER
POCASSET
SUMMER ST
PONTIAC AVE
PENN
OAK LAWN AVE
HATFIELD
KNIGHT ST
PAWTUXET RIVER
BROOK
THREE PONDS
BOULEVARD
OLNEY AVE
POST ROAD
BALD HILL ROAD
COMMONWEALTH AVE
TOLL GATE ROAD
MEMORIAL HOSPITAL
GREENWICH AVE
MAIN
JEFFERSON
BOSTON
THEODORE FRANCIS
GREEN STATE
AIRPORT
CENTERVILLE
HARDIG BROOK RD
LONG STREET
WEST SHORE RD
STRAWBERRY FIELD ROAD
SCALE IN FEET



NOTES

1. Plan traced from an enlargement of United States Geological Survey (U.S.G.S.) Quadrangle Maps of Providence and East Greenwich Rhode Island with appropriate revisions
2. Only commercial and industrial buildings having a bearing on project report are shown
3. Although pumping stations are required for all local protection projects only those controlling major interior drainage areas are shown
4. As the protective enclosure falls within the freeboard range, sandbags placed as shown during a flood emergency would provide the necessary protection

LEGEND

City or County Boundary Line
Town Boundary Line
Municipal Sewage Treatment Facility
U.S.G.S. Gaging Station
Tributaries
Ponds or Major Rivers
Local Protection Projects
Earth Dikes
Concrete Flood Walls
Channel Modification

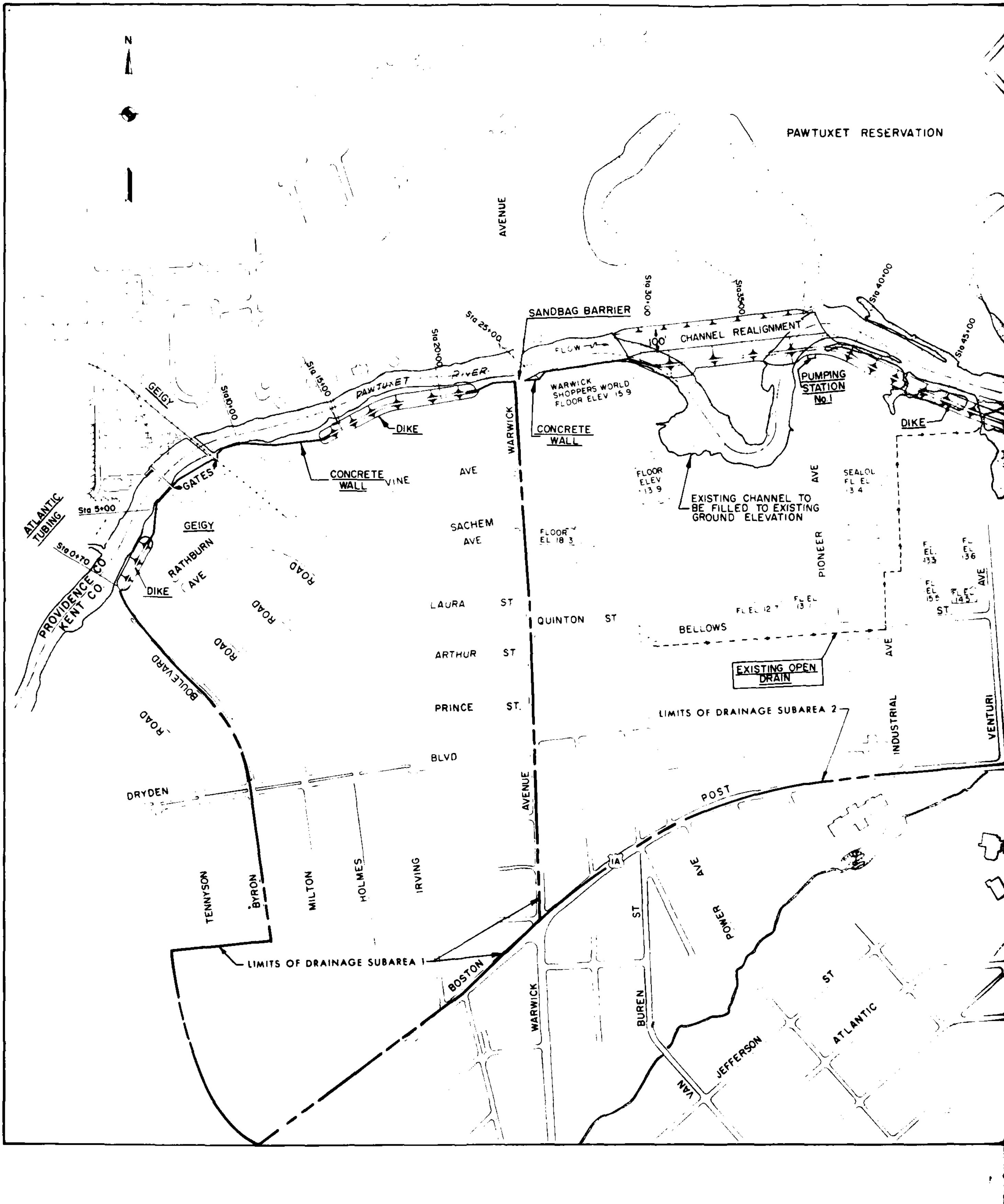
IN FEET
1000 2000

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

ALTERNATE A-1
100 YEAR PROJECT FLOOD

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.



N
PAWTUXET RESERVATION
AVENUE
SANDBAG BARRIER
CHANNEL REALIGNMENT
100'
FLOW
PAWTUXET RIVER
Sta 25+00
Sta 20+00
Sta 15+00
Sta 10+00
Sta 5+00
Sta 0+70
Sta 30+00
Sta 35+00
Sta 40+00
Sta 45+00
WARWICK SHOPPERS WORLD FLOOR ELEV 15.9
CONCRETE WALL
PUMPING STATION No. 1
DIKE
GEIGY
GATES
CONCRETE WALL
VINE
AVE
WARWICK
FLOOR ELEV 13.9
EXISTING CHANNEL TO BE FILLED TO EXISTING GROUND ELEVATION
ATLANTIC TUBING
PROVIDENCE CO
KENT CO
GEIGY
RATHBURN
AVE
DIKE
ROAD
SACHEM
AVE
FLOOR EL 18.3
PIONEER
LAURA ST
QUINTON ST
BELLOWS
ARTHUR ST
EXISTING OPEN DRAIN
PRINCE ST.
LIMITS OF DRAINAGE SUBAREA 2
INDUSTRIAL
VENTURI
BOULEVARD
BLVD
DRYDEN
AVENUE
POST
1A
TENNYSON
BYRON
MILTON
HOLMES
IRVING
ST
AVE
POWER
LIMITS OF DRAINAGE SUBAREA 1
BOSTON
WARWICK
BUREN
VAN
JEFFERSON
ATLANTIC
ST

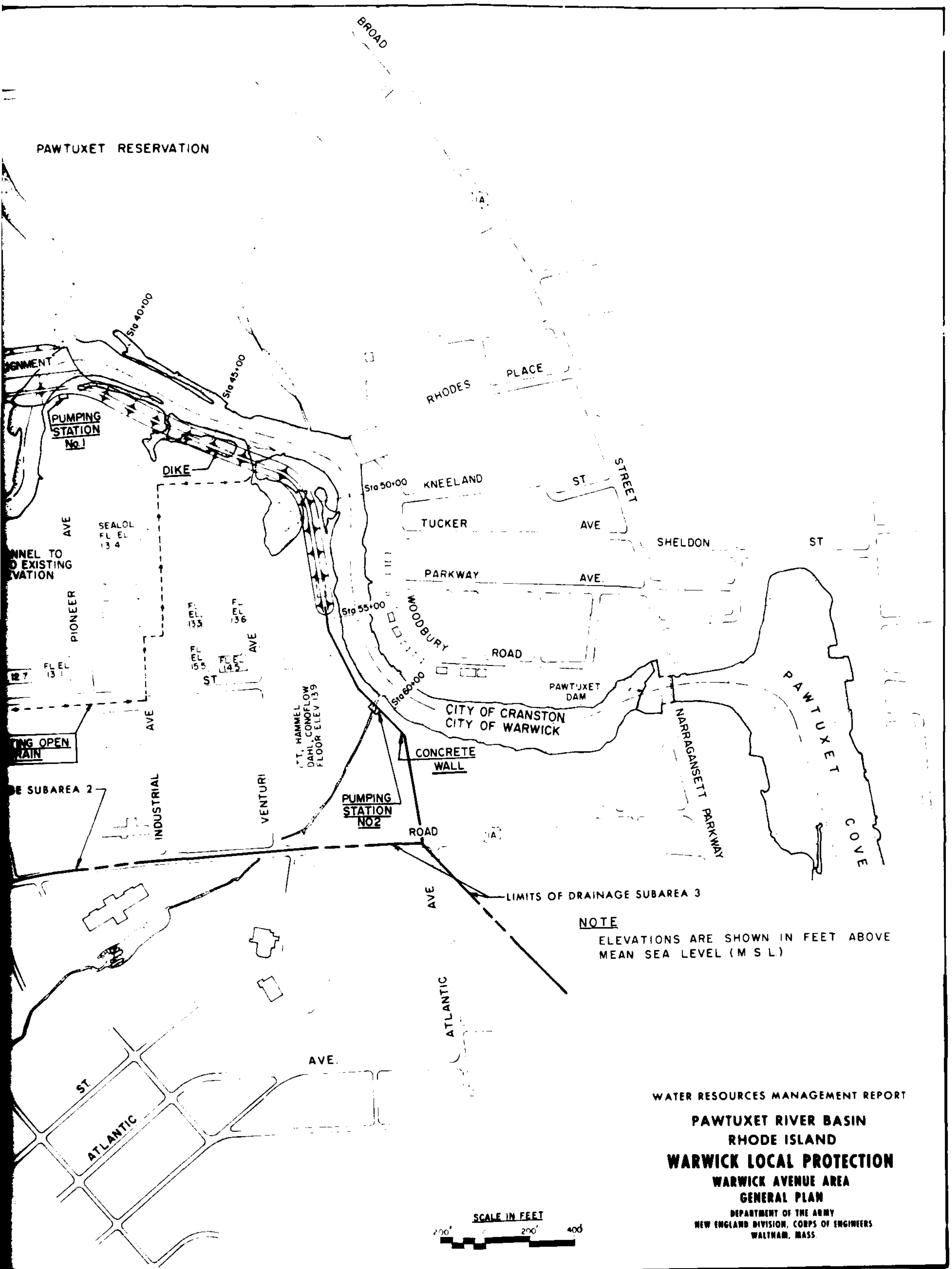
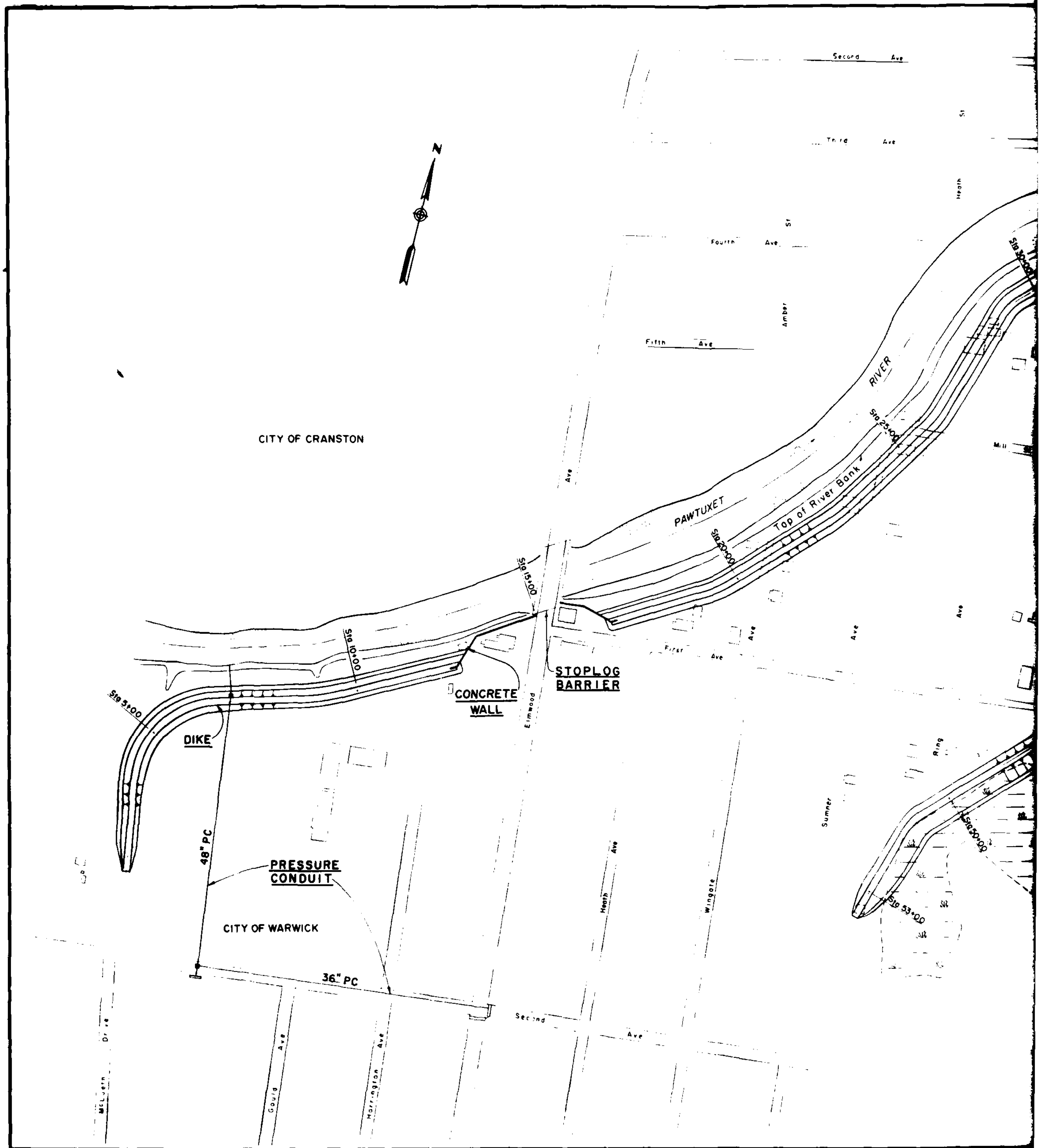
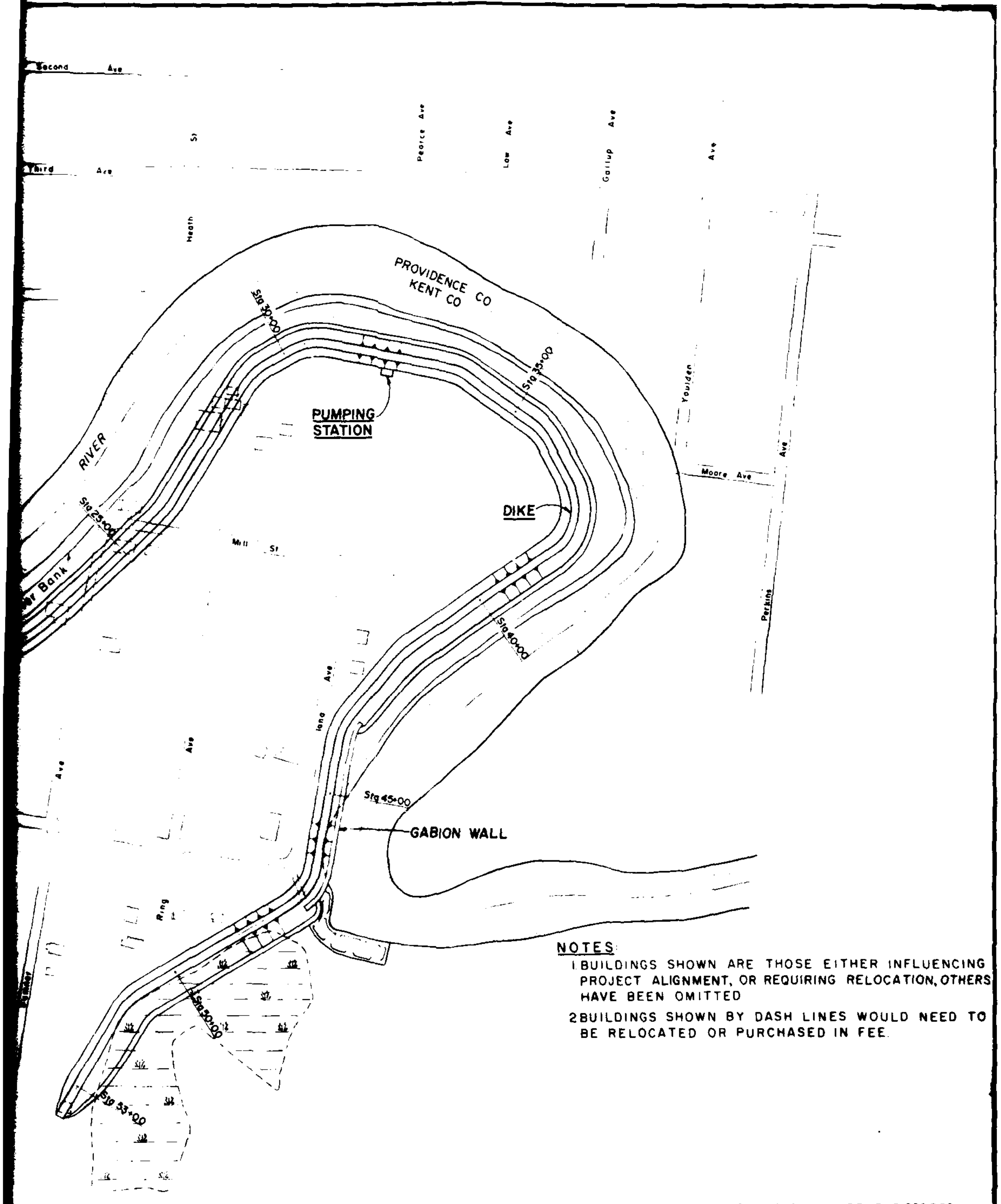

BROAD
PAWTUXET RESERVATION
Sta 40+00
Sta 45+00
Sta 50+00
Sta 55+00
Sta 60+00
PUMPING STATION No.1
DIKE
SEALOL FL EL 13.4
PIONEER AVE
INDUSTRIAL AVE
VENTURI AVE
ST.
RHODES PLACE
KNEELAND ST
STREET
TUCKER AVE
SHELDON ST
PARKWAY AVE.
WOODBURY ROAD
PAWTUXET DAM
CITY OF CRANSTON
CITY OF WARWICK
CONCRETE WALL
PUMPING STATION NO2
ROAD
NARRAGANSETT PARKWAY
PAWTUXET COVE
LIMITS OF DRAINAGE SUBAREA 3
SUBAREA 2
ATLANTIC AVE
AVE.
ATLANTIC ST.
NOTE
ELEVATIONS ARE SHOWN IN FEET ABOVE MEAN SEA LEVEL (M S L)
SCALE IN FEET
200' 0 200' 400'
WATER RESOURCES MANAGEMENT REPORT
PAWTUXET RIVER BASIN
RHODE ISLAND
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
GENERAL PLAN
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE III-4



CITY OF CRANSTON
CITY OF WARWICK
PAWTUXET
RIVER
Top of River Bank
Sta 5+00
Sta 10+00
Sta 15+00
Sta 20+00
Sta 25+00
Sta 30+00
Sta 50+00
Sta 53+00
DIKE
CONCRETE WALL
STOPLOG BARRIER
PRESSURE CONDUIT
48" PC
36" PC
Second Ave
Third Ave
Fourth Ave
Fifth Ave
First Ave
Amber St
Heath St
Elmwood Ave
Heath Ave
Wingate
Sumner Ave
Ring
Gould Ave
Harrington Ave
McGovern Drive
Mill



NOTES:

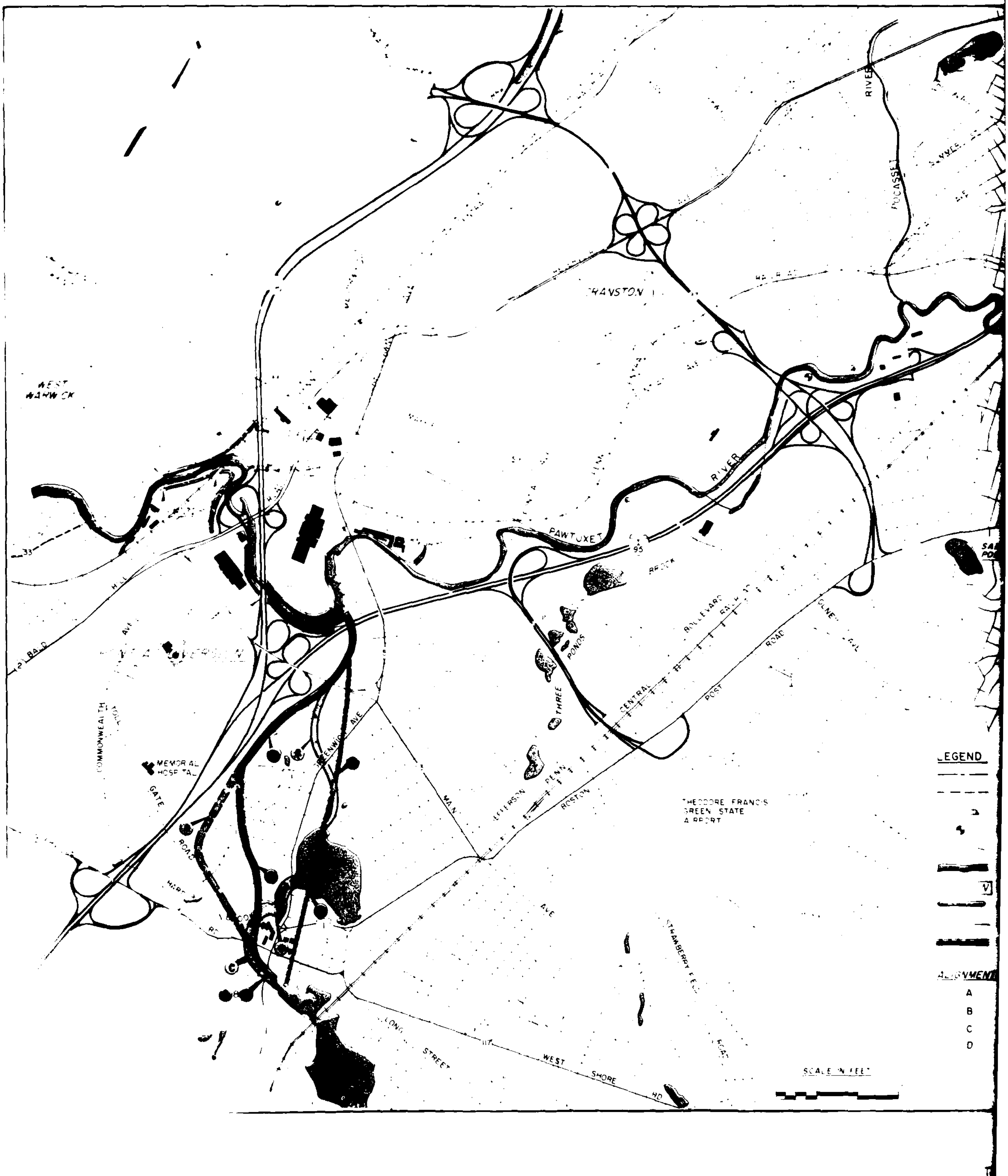
1. BUILDINGS SHOWN ARE THOSE EITHER INFLUENCING PROJECT ALIGNMENT, OR REQUIRING RELOCATION, OTHERS HAVE BEEN OMITTED
2. BUILDINGS SHOWN BY DASH LINES WOULD NEED TO BE RELOCATED OR PURCHASED IN FEE.

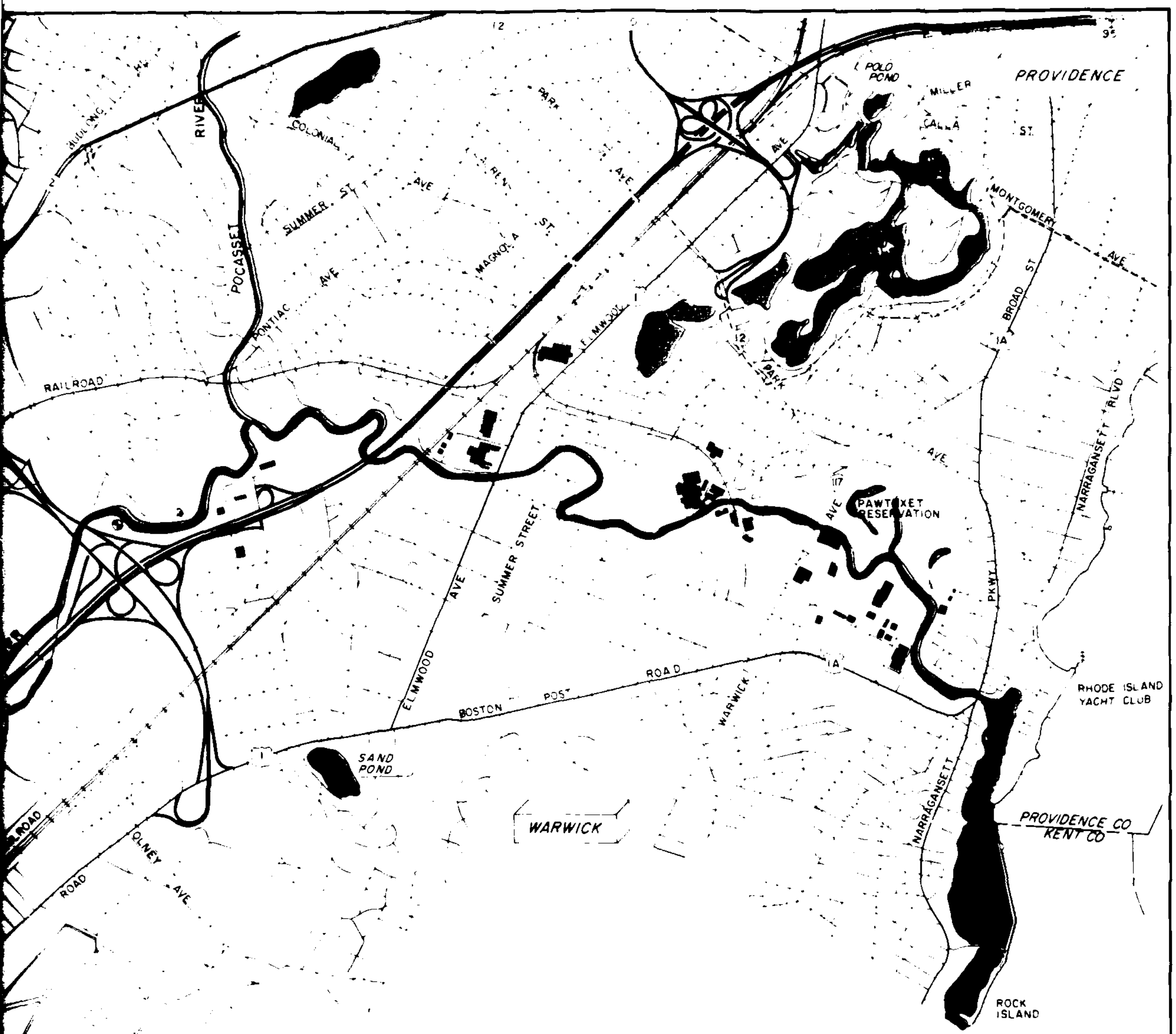
WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

WARWICK LOCAL PROTECTION
ELMWOOD AVENUE AREA
GENERAL PLAN

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.


WEST WARWICK
CRANSTON
PAWTUXET
RIVER
POCASSET
95
MEMORIAL HOSPITAL
COMMONWEALTH
GATE
ROAD
GREENWICH AVE
THREE
PONDS
BROOK
CENTRAL
BOULEVARD
POST
ROAD
BOSTON
MAIN
THEODORE FRANCIS GREEN STATE AIRPORT
STRAWBERRY FIELD
LONG
STREET
117
WEST
SHORE
RD
AVE
LEGEND
ALIGNMENT
A
B
C
D
SCALE IN FEET



LEGEND

- City or County Boundary Line
- Town Boundary Line
- Municipal Sewage Treatment Facility
- U.S.G.S. Gaging Station
- Tributaries
- Ponds or Major Rivers
- Flood Protection Projects
- Earth Dikes
- Concrete Flood Walls
- Channel Modification

PONTIAC DIVERSION

ALIGNMENTS	OPEN CHANNEL	TUNNEL	REMARKS
A			Concrete
B			Concrete
C			Concrete
D			Concrete Lined

SCALE IN FEET

NOTES

1. Plan traced from an enlargement of United States Geological Survey (U.S.G.S.) Quadrangle Maps of Providence and East Greenwich Rhode Island with appropriate revisions
2. Only commercial and industrial buildings having a bearing on project report are shown
3. Although pumping stations are required with the diversion project only one controlling a major interior drainage area is shown

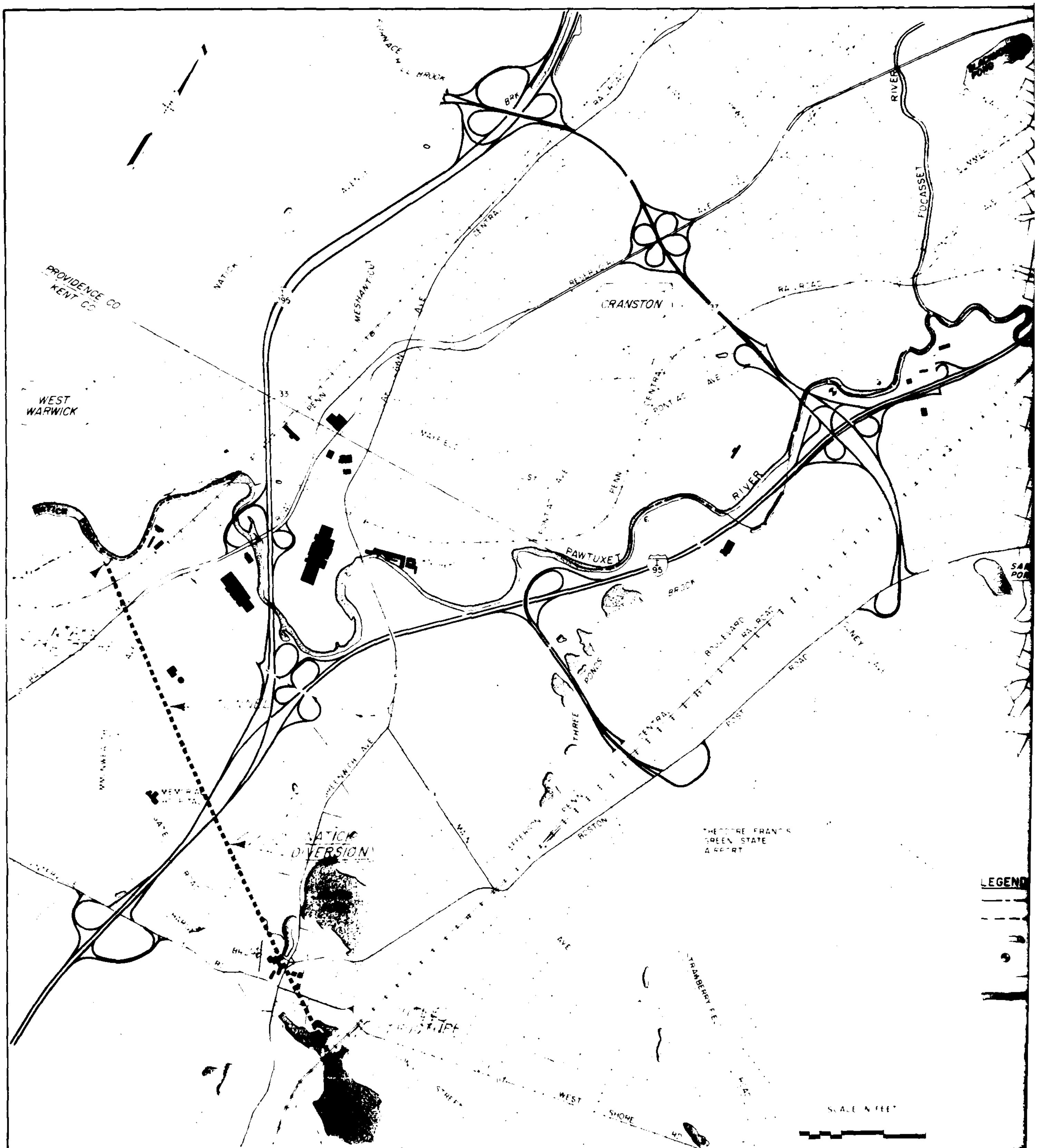
WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

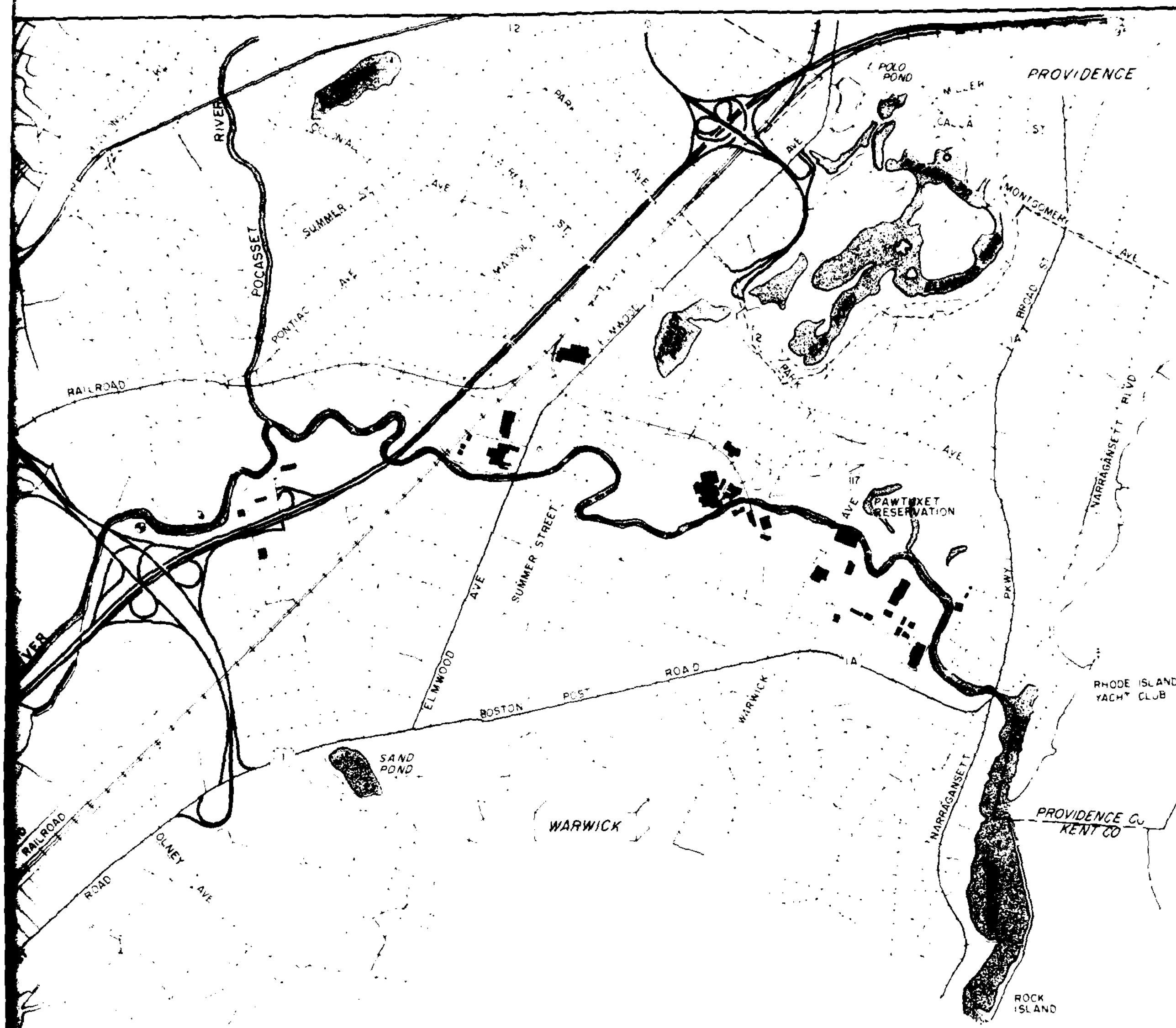
PONTIAC DIVERSION

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

PLATE III-6



PROVIDENCE CO
KENT CO
WEST
WARWICK
CRANSTON
95
PAWTUXET
RIVER
POCASSET
RIVER
NATICK
DIVERSION
BOULEVARD
BOSTON
WEST
SHORE
LEGEND



NOTES

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2. Only commercial and industrial buildings having a bearing on project report are shown

LEGEND

- City or County Boundary Line
- Town Boundary Line
- Municipal Sewage Treatment Facility
- U.S.G.S. Gaging Station
- Tributaries
- Ponds or Major Rivers

SCALE IN FEET

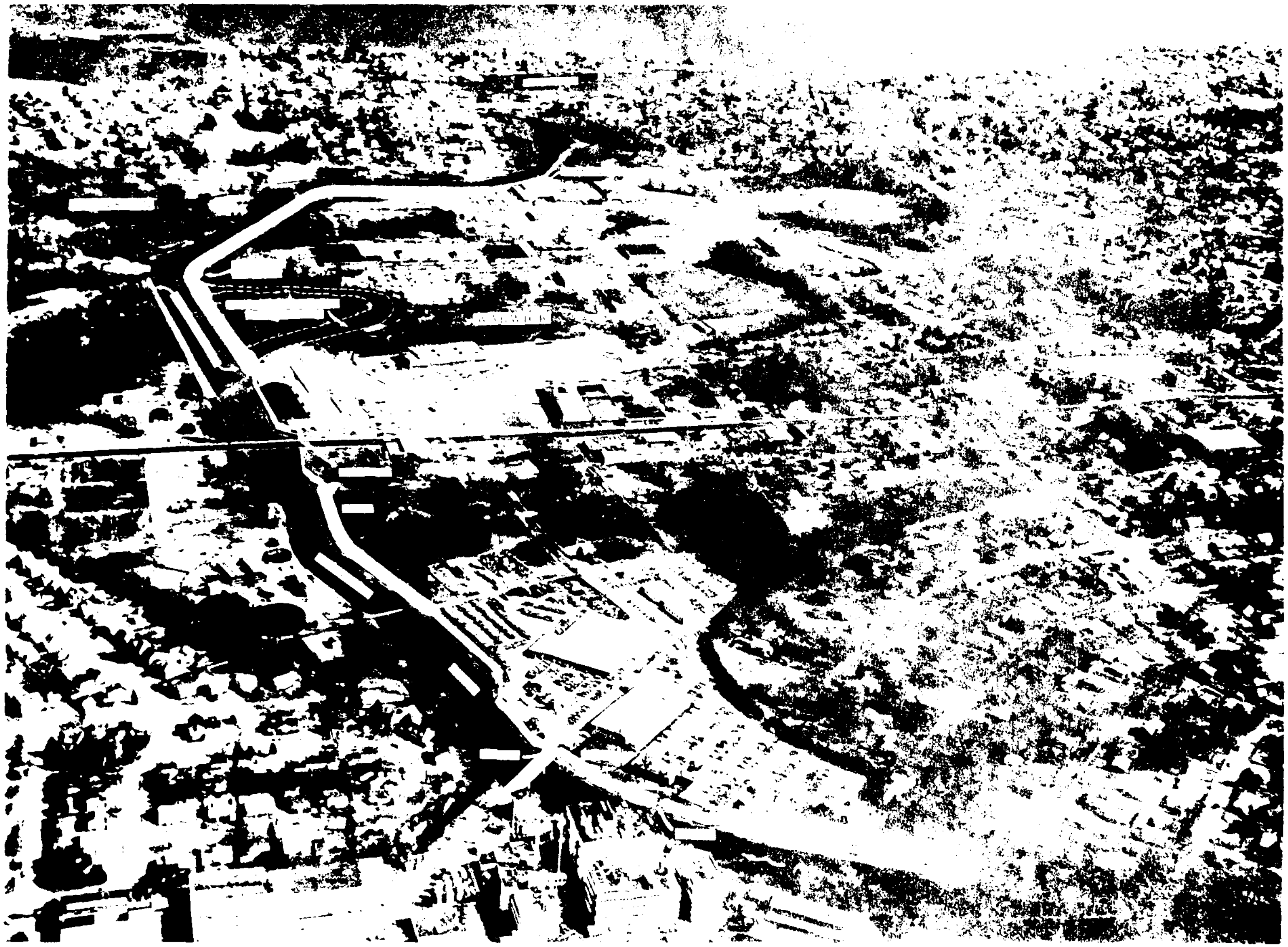
WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

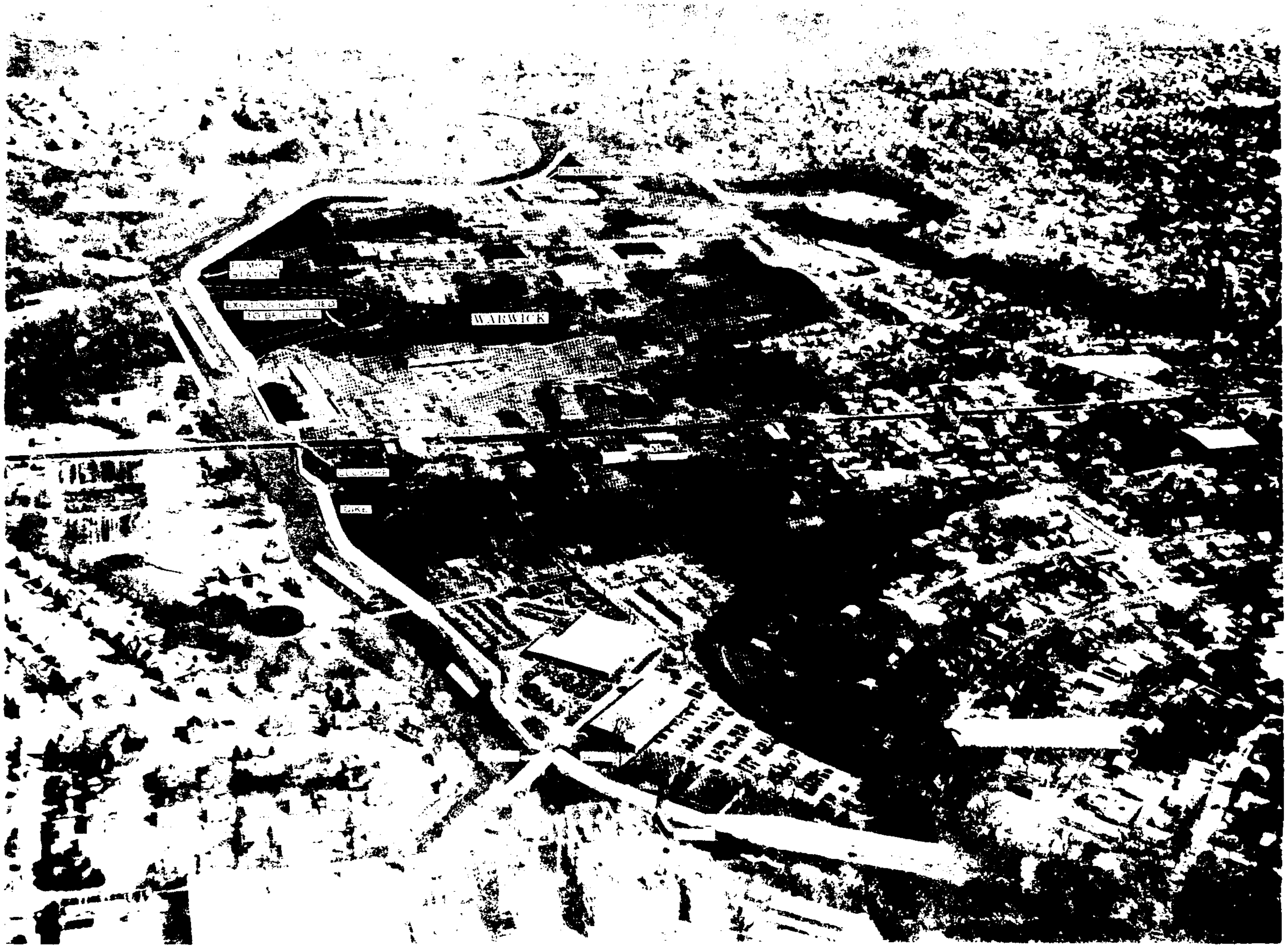
NATICK DIVERSION

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE III.7



WARWICK LOCAL PROTECTION - Warwick Avenue Area



WARWICK LOCAL PROTECTION · Warwick Avenue Area

WARWICK LOCAL PROTECTION - Elmwood Avenue Area

WARWICK LOCAL PROTECTION - Elmwood Avenue Area

protection at minimum cost and environmental impact by increasing the height of the proposed dam by about 2.5 feet, thus giving additional flood control storage equivalent to about six inches of runoff over a drainage area of about 30 square miles.

2. Management of Scituate and Big River Reservoirs in conjunction with each other presents an opportunity to optimize the operations of both reservoirs so that each reservoir could provide floodwater storage capabilities without jeopardizing the principal purpose of each reservoir, namely water supply.

3. Erosion control measures, if needed, should be instituted by local interests during construction of the Big River Reservoir, in coordination with programs of the Soil Conservation Service.

CONCLUSIONS

While nonstructural floodproofing was found to be economically infeasible as a single action program, it was retained for further consideration as a supplement to the Natick Diversion and the Elmwood Avenue and Warwick Avenue local protection projects, which were found to warrant further consideration. Reservoir construction, reservoir management and erosion control during reservoir construction were retained as future action programs. The No Action and regulatory measures programs were also retained for further evaluation as supplements to specific corrective measures.

CHAPTER IV

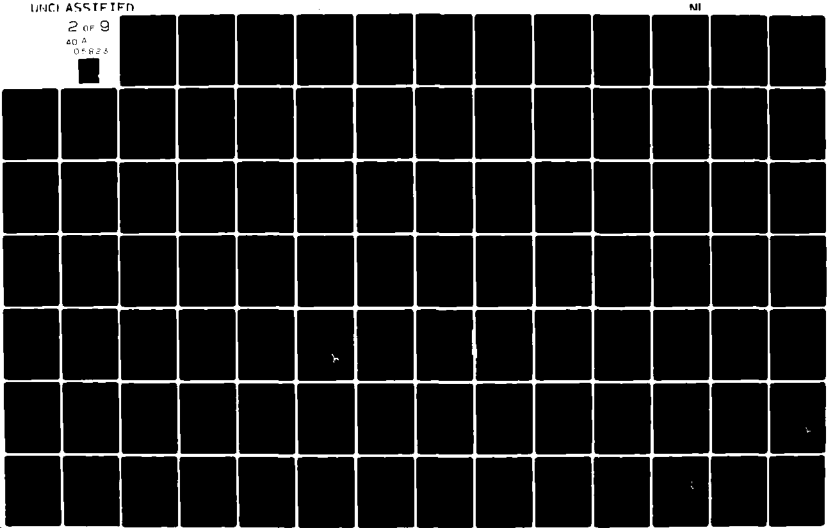
ASSESSMENT AND EVALUATION
OF
DETAILED PLANS

TABLE OF CONTENTS

AD-A105 823 CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV F/G 13/2
BIG RIVER RESERVOIR PROJECT - PAWCATUCK RIVER AND NARRAGANSETT --ETC(U)
JUL 81

UNCLASSIFIED NL

2 OF 9
AD A
05823



TABLES

ASSESSMENT & EVALUATION OF DETAILED PLANS

PLAN A

PLAN DESCRIPTION

This alternative would consist of the Natick Diversion with a 30-foot finished diameter concrete shell. It is the same alternative studied during the Formulation of Preliminary Plans stage. At this finished diameter it is capable of discharging Pawtuxet River floodflows at a maximum of 12,000 to 14,400 CFS depending upon tidal conditions into the Apponaug Cove - Greenwich Bay area. The 12,000 cfs would be at a maximum design tide occurrence whereas the 14,400 cfs flow would be when conditions are of an extreme low tide. The intake and discharge shafts would be located at the locations described previously.

IMPACT ASSESSMENT

This plan would provide a very high degree of flood protection to the mainstem of the Pawtuxet River, a 77 percent reduction in total annual losses including allowable projected growth. The areas remaining subject to significant flooding with this alternative flooding are the Warwick Industrial Park, the Ciba Geigy Atlantic Tubing Complex in Cranston, and the Belmont-Norwood residential area in Warwick. These areas, however, would realize substantial reductions in floodwater depths. A summary matrix on page 47 illustrates the overall effect of this plan on all the significant problem areas identified in the Problem Identification Chapter.

There are potentially harmful effects of the diversion which may be felt in the Greenwich Bay area. In most cases the affected medium would be early life stages of shellfish and other marine biota due to the reduced salinity caused by the fresh water intrusion. In addition, the introduction of excess coliform bacteria within the bay would close the shellfishing flats for a period of up to seven days under the maximum storm discharge.

The remaining adverse impacts on environmental quality would occur during construction. Air quality standards may also be compromised due to excavation activity. Increased traffic could pose more significant problems regarding safety and air quality standards.

Blasting would be required at the site. However, careful regulation of the charges will be mandated so as to negate any possible damaging effect to nearby homes. Also, there would be a large amount of rock spoil as a result of the excavation activity. Social well-being would be improved due to the increased sense of security gained as a result of the lifetime protection afford by this plan.

Construction of this project would produce new jobs and increase spending in the area. Since commercial and industrial firms would be afforded a high degree protection, expansion of these establishments would also be possible.

EVALUATION AND TRADE-OFF ANALYSIS

This plan is effective in providing a high level of protection to the area of concern by reducing future flood stages and thereby reducing future losses. This plan satisfies the planning objectives but there would still be some temporary adverse impacts to marine life in Apponaug Cove and Greenwich Bay and some temporary effects to air and water quality in the area.

This is not to say that the overall water quality of the river will not improve. Measures have or will be taken to control other sources of pollution which are not related to the diversionary tunnel. Included would be point as well as nonpoint sources of pollution.

There is considerable uncertainty associated with the affects on marine biota as a result of the mixing of salt and fresh water. This is due to the fact that this portion of the analysis was done using a mathematical model to simulate the affects under the worst possible conditions. These conditions being a complete mixing of the fresh water from the river with the saline water in Apponaug Cove when no turbulence at the outlet site existed (which would normally aid in dispersing the discharge) and also that water quality of the Pawtuxet River would not improve by the time the diversion would be operative.

Appraise System of Accounts

NED Objective - The project first cost of Plan A is $57,800,000, the project benefits are $4,042,000 and the annual charges are $4,650,000. There would also be an undetermined amount of capital lost due to a reduction in shellfishing days in Greewich Bay.

EQ Objective - During construction air and noise pollution will increase and disposal of rock spoil may also have some adverse environmental effects. Although the resultant structures will be aesthetically pleasing they will depart from the natural state of the river. During and immediately after a storm discharge there will be an increase in the coliform counts in Apponaug Cove and Greenwich Bay, as well as a reduction in the salinity concentrations which may cause mortality to some species.

SWB Objective - There will be an increased sense of security among area residents as a result of the decreased flood threat. However, there could be a decline in public confidence due to the presence of the tunnel beneath homes. The homes overlying the tunnel will have a permanent easement placed upon their deed. This may result in a less salable property. An undetermined number of days of shellfishing will be lost after a storm discharge and during construction there will be inceased traffic at the contruction site.

RD Objective - Employment opportunities for skilled and unskilled workers will increase during construction. After completion of the tunnel there will be an increase in the availability of new land for development.

Specific Evaluation Criteria

Acceptability - The general acceptability for this project is very low due to the possible environmental effects and the ever-present stigma of the tunnel beneath a residential area.

Completeness - All necessary actions for successful completion of this alternative have been included.

Effectiveness and Efficiency - The plan satisfies the planning objectives, however, pollution standards may be compromised.

Certainty - Low

Geographic Scope - Water is transferred out of the Pawtuxet Basin to the Narragansett Bay local drainage area.

NED Benefit-To-Cost Ratio - 0.87

Reversibility - No

Stability - Low

MITIGATION REQUIREMENTS

As mentioned previously, an undetermined amount of shellfishing days could be lost due to impacts on Greenwich Bay. On the average, it would amount to seven days per year. Therefore, shellfishermen would have to be reimbursed to cover capital lost from not being able to fish.

Additional traffic control would be required in the construction area in addition to restriction on pollution emissions. Blasting would be controlled to minimize any adverse social affects.

IMPLEMENTATION RESPONSIBILITIES

Cost Allocation

All costs of this project are allocated to flood control. The cost is shown below.

Project Cost	$ 57,798,000
Annual Charges	$ 4,650,000

Cost Apportionment

Table IV-2 summarizes distribution of costs between Federal and non-Federal interests.

Federal Responsibilities

As the flood control benefits to be derived by the Natick Diversion would accrue to three municipalities, namely, the town of West Warick and the cities of Cranston and Warwick, the project would be regional in character. In this regard, all costs associated with construction, operation and maintenance of the Diversion project under existing legislated authority would be Federally funded. It would also be operated and maintained by the Federal Government.

Non-Federal Responsibilities

As previously covered, the Natick Diversion would be a total Federal responsibility under the existing legislated mandates. However, several prerequisites would be required of the local interests to prevent further encroachment on the flood plain that could reduce the effectiveness of the diversion project. These include:

a. Enforcement in all downstream reaches of the 100-year flood plain and the other basic requirements of the National Flood Insurance Program.

b. Publicizing flood plain information in the area concerned and providing this information to zoning, banking and other groups for their guidance and leadership in preventing unwise future development in the flood plains, and in adapting such regulations as may be necessary to insure compatibility between future development and protection levels provided by the project.

c. At least annually, informing affected interests regarding the limitation of the protection afforded by the project.

Local interests would be responsible for implementing the necessary flood plain regulations required by the National Flood Insurance Program, so that all interested parties would be eligible to purchase insurance under the program. Local communities would also be encouraged to implement additional land use controls, such as evaluation and institution of subdivision regulations, building codes, land easements and related measures. In this regard, these controls would insure against further encroachment of the flood plains as well as guide their development and redevelopment so as to lessen future flood losses.

PUBLIC VIEWS

Heavy opposition was directed toward this project by both private citizens as well as municipal and other Federal agencies. Their objections are capsuled below.

Views of Federal Agencies

Comments from Federal agencies regarding the diversion tunnel were directed mainly at environmental concerns and an alledgedly weak environmental impact statement. Specifically, impacts on Apponaug Cove and Greenwich Bay causing mortality in early life stages of shellfish and other marine biota were cited by the Environmental Protection Agency, the Department of Health Education and Welfare, the U.S. Department of Commerce, and the Fish and Wildlife Service. These effects, such as the mixing of fresh and saline water in addition to increased coliform counts due to the fresh water diversion, could cause a halt to the shellfishing activities for several days according to these agencies.

Views of Non-Federal Agencies and Others

In addition to the Environmental questions raised, area residents questioned the stability of the tunnel during seismic activity. Some citizens objected to living above the diversion while it afforded them no protection at all. There was an overall scepticism about the Natick Diversion in regards to its effectivness and necessity. Out of basin individuals and city and State agencies preferred a system of walls and dikes in conjunction with a sound land use program in lieu of the diversionary tunnel. A summary of the four public meetings held in 1969, 1975, 1976 and 1977 will be found in Appendix 3. Also, included is correspondence relating to each meeting in addition to comments on the draft environmental impact statement released in 1976.

Plan B

PLAN DESCRIPTION

The structural elements of this alternative would consist of the Natick Diversion with a 30-foot diameter tunnel and the Warwick Avenue and Elmwood Avenue local protection projects. From the various local protection measures evaluated as single action measures, plans evolved that would provide local protection measures for extreme northeastern Warwick extending from the lower limits of Zone 6 and including all damaged portions of Zones 7 and 8. A series of dikes, floodwalls and other structures would provide full protection, to the SPF event as modified by Natick Diversion, to the residential-commercial area in the vicinity of Elmwood Avenue (U.S. 1) and to the Warwick Industrial Park and the adjacent residential-commercial area in the vicinity of Warwick Avenue.

IMPACT ASSESSEMENT

Provision of the 30-foot diameter Natick Diversion and the Elmwood Avenue-Warwick Avenue protective measures would reduce average annual existing losses in the lower basin to approximately $235,000. With the 30-foot diameter diversion tunnel and the Warwick protective measures, most of the residual losses would occur within the Cranston portions of Zones 4B, 6, 7, and 8. The remaining losses in Warwick Zones 4, 5, and 6 and the West Warwick portion of Zone 4 would be minimal following reductions by the Natick Diversion. Summary matrix located on page 47 depicts the effectiveness of this plan.

The area that would receive protection from the Elmwood Avenue local protection project inclosure consists mainly of one family residential structures with about 10 small to moderately sized commercial firms that would begin to be inundated in the range of 2 to 4 percent frequency storm event. Because of increasing urbanization in upstream areas, the frequency of flooding has increased to a point where several times a year some overbank-road flooding and measurable cellar flooding occurs. Most of the homes in the area have installed sump pumps and some have eliminated the usage of the cellar for any significant purpose. In many instances the pumps are not of sufficient size to handle the inflow of water. Recently, about every five years significant basement-road flooding occurs, and at about a 10 to 15 year recurrence interval first floor flooding occurs in about 7 homes.

Because of the projected increase in river stages due to uncontrolled increasing nonflood plain urbanization upstream, more frequent flooding can be expected with a subsequent increase in damages to both a specific flood event and to annual losses.

Impacts attributed to the tunnel given in alternative "A" will apply to alternative "B" as well. Additional increases in jobs and the work force will be realized by construction of the two local protection projects. Also, more land will be available for developing resulting from the protection afforded by the wall and dike systems.

Elmwood local protection project would involve relocating 7 homes. This is necessary because of the land requirements of the dike. The resultant dike structure can be made aesthetically pleasing although it would depart from the natural topography of the surrounding lands.

EVALUATION AND TRADE-OFF ANALYSIS

As this alternative involves the Natick Diversion its response to the evaluation criteria is the same as that stated for alternative A. The plan is effective in providing a high level of protection to those areas given in alternative A in addition to the residential - commercial sections protected by the dikes mentioned previously. Implementation of alternative B would reduce the number of ownerships affected by the 100-year flood level from 471 to 148.

A component of this alternative would be the future action elements consisting of flood control storage at Big River Reservoir and the regulation/management of Scituate Reservoir, although not an integral portion of this plan.

<u>Appraise System Of Accounts</u>

<u>NED Objective</u> - The project first cost of Plan B is $69,380,000, the project benefits are $5,000,000 and the annual charges are $5,552,000. An undetermined amount of capital would be lost due to a reduction in shellfishing days in Greenwich Bay and approximately seven homes would be purchased at the Elmwood site.

<u>EQ Objective</u> - Same as Plan A. During construction air and noise pollution will increase and disposal of rock spoil may also have some adverse effects. Although the resultant structures will be aesthetically pleasing, they will depart from the natural state of the river. During and immediately after a storm discharge there will be an increase in the coliform counts and a reduction in salinity in Greenwich Bay.

<u>SWB Objectives</u> - Same as Plan A plus the relocation of seven homes. There will be an increased sense of security among area residents as a result of the decreased flood threat. However, there could be a decline in public confidence due to the presence of the tunnel beneath homes and the additional problem of an easement on the titles of affected properties. An undetermined number of days of shellfishing will be lost after a storm discharge and during construction there will be increased traffic at the construction site.

RD Objective - Same as Plan A. Employment opportunities for skilled and unskilled workers will increase during construction. After completion of the tunnel there will be an increase in the availability of new land for development.

Specific Evaluation Criteria

Acceptability - Same as Plan A. The acceptability fo this project is very low due to the possible environmental effects and the ever-present stigma of the tunnel beneath a residential area. These are covered in more detail in the public views section and the public involvement appendix.

Completeness - All necessary actions for successful completion of this alternative has been included.

Effectiveness and Efficiency - Same as Plan A except this plan is the most costly.

Certainty - Low

Geographic Scope - Water is transferred at the Pawtuxet Basin to the Narragansett Bay local drainage area.

NED Benefit-to-Cost Ratio - 0.90

Reversibility - No

Stability - Low

MITIGATION REQUIREMENTS

Those pertaining to the Natick Diversion are the same as Plan A. Some storage will be lost due to construction of the local protection projects but increases in downstream flood stages will be minimal. In either case, any additional increase in flood stage will be mitigated by the additional flood control storage provided at the proposed Big River Reservoir.

IMPLEMENTATION RESPONSIBILITIES

Cost Allocation

All costs of this project are allocated to flood control.

Project Cost	$69,381,000
Annual Charges	$ 5,552,000

Cost Apportionment

Table IV-2 summarizes the distribution of costs between Federal and non-Federal interests.

Federal Responsibilities

As the flood control benefits to be derived by the Natick Diversion would accrue to three municipalities, namely, the town of West Warwick and the cities of Cranston and Warwick, the project would be regional in character and wholly Federal under existing legislated authorities. In this regard, all costs associated with construction, operation and maintenance of the diversion project would be Federally funded. The diversion project would be operated and maintained by the Federal Government.

The benefits accruing to the Warwick Local Protection would be local in nature and would entail the usual conditions of local cooperation as stated in the following paragraphs of non-Federal responsibilities. The local protection project would be constructed by the Federal Government and upon its completion would be turned over to the city of Warwick for operation and maintenance. Federal cost involvement beyond this stage would be limited to Federal personnel costs associated with periodic inspection of the project.

While participation in the National Flood Insurance Program would be a local responsbility, there would be attendant responsibilities, those of providing guidance and technical assistance to the local communities. Part of this guidance would include encouragement that all basin communities consider additional land use controls as needed to minimize future adverse runoff effects as the basin becomes more urbanized.

Non-Federal Responsibilities

As previously covered, the Natick Diversion would be a total Federal responsibility. However, several prerequisites would be required of the local interests to prevent further encroachment on the flood plain that could reduce the effectiveness of the diversion project:

a. Enforcement in all downstream reaches of the 100-year flood plain and the other basic requirements of the National Flood Insurance Program.

b. Publicizing flood plain information in the area concerned and providing this information to zoning, banking and other groups for their guidance and leadership in preventing unwise future development in the flood plains, and in adapting such regulations as may be necessary to insure compatibility between future development and protection levels provided by the project.

c. At least annually, informing affected interests regarding the limitation of the protection afforded by the project.

As the benefits accruing to the Warwick Avenue Local Protection and the Elmwood Avenue Local Protection Projects would occur principally within Warwick, the project would entail the conditions of local cooperation in accordance with Section 3 of the Flood Control Act of 1936, as amended, and in conformance with the policy expressed in EM 1120-2-101. Local interests would be required to give assurances satisfactory to the Secretary of the Army that they would:

a. Provide without cost to the United States, all lands, easements, and rights-of-way necessary for construction of the project;

b. Hold and keep the United States free from damages due to the construction works;

c. Maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army;

d. Provide, without cost to the United States, all alterations and replacements of existing utilities including bridges, highways, sewers and railroad modifications and relocations other than railroad bridges and their approaches which may be required for the construction of the project;

e. Prescribe and enforce regulations to prevent encroachment on both the improved and unimproved channel;

f. Prohibit encroachment on project ponding areas and, if the capacity of these areas is impaired, promptly provide substitute ponding capacity or equivalent pumping capacity without cost to the United States; and

g. Comply with the requirement specified in Section 210 and 305 of Public Law 91-646, 91st Congress, approved 2 January 1971, entitled, "Uniform Relocation Assistance and Real Property Policies Act of 1970."

Local interests would be responsible for implementing the necessary flood plain regulations required by the National Flood Insurance Program, so that all interested parties would be eligible to purchase insurance under the program. Local communities would also be encouraged to implement additional land use controls, such as evaluation and institution of subdivision regulations, building codes, land easements and related measures. In this regard, this would insure against further encroachment of the flood plains as well as guide their development and redevelopment so as to lessen future flood losses.

PUBLIC VIEWS

Views of Federal Agencies

Those comments associated with the Natick Diversion with respect to the environment are the same as those for alternative "A" which proposed the tunnel as a single action measure.

Views of Non-Federal Agencies and Others

Local interests once again opposed this plan because of the inclusion of the Natick Diversion. In addition, all subsequent alternatives that included the diversion were objected to mostly on an environmental impact basis.

While the two local protection projects were supported, cost became the main concern of the city of Warwick. Since the Natick Diversion was regional in scope, it would be funded totally by the Federal Government. This is not the case for a local protection measure. The city would have to finance any land acquisition and the operation and maintenance of the project. This philosophy was objected to by Warwick city officials. They feel that the problems in these areas should be considered regional in nature since development in upstream areas has contributed to increases flood stages at downstream locations.

PLAN C

PLAN DESCRIPTION

This alternative would consist of Natick Diversion with a 21-foot diameter tunnel and the Warwick Avenue-Elmwood Avenue local protection projects. The series of dikes, floodwalls and other structures are basically the same as the previous alternative. However, the walls and dikes are several feet higher than those considered in Alternative B as the diversion cannot divert as much floodwater into Apponaug Cove. Both local protection projects were justified as single action measures in the intermediate level of detail and combined with the single purpose Natick Diversion with a 21-foot diameter discharge tunnel.

Provision of this alternative would reduce average annual losses in the lower basin to approximately $520,000.

A component of this alternative would be the future action elements consisting of flood control storage at Big River Reservoir and the regulation/management of Scituate Reservoir, although not integral portions of this alternative.

IMPACT ASSESSMENT

Same as Plan B.

EVALUATION AND TRADE-OFF ANALYSIS

The plan provides an SPF level of protection to the Warwick Industrial Park and also the lower limits of Zone 6 and Zones 7 and 8 in Warwick. The 21-foot diameter tunnel reduces flood stages as effectively as the 30-foot diameter tunnel up to the 100 year flood. At a 500 year event or 0.2 per cent chance of occurrance flood, reductions in stage are significantly higher using a 30-foot diameter diversion tunnel for zones 4, 5 and 6.

This plan is extremely effective in providing a high level of protection to the areas of concern. While the planning objectives would be satisfied, there would be some temporary adverse impacts to marine life and air and water quality.

Appraise System of Accounts

NED Objective - The project first cost of Plan C is $52,890,000, the project benefits are $4,363,000 and the annual charges are $4,260,000. As with Plans A and B, there will be an undetermined amount of lost capital due to a reduction in shellfishing. Also, as

in Plan B the purchase of approximately seven homes will be necessary at the Elmwood site.

EQ Objective - Same as Plan A.

SWB Objective - Same as Plan A plus the relocation of seven homes.

RD Objective - Same as Plan A.

Specific Evaluation Criteria

Acceptability - As this plan involves the Natick Diversion, its acceptability is low.

Completeness - All necessary actions for successful completion of this alternative have been included.

Effectiveness & Efficiency - Same as Plan A.

Certainty - Low.

Geographic Scope - Water is transferred out of the Pawtuxet Basin to local drainage area.

NED Benefit-to-Cost Ratio - 1.03

Reversibility - No.

Stability - Low.

MITIGATION REQUIREMENTS

Same as Plan B.

IMPLEMENTATION RESPONSIBILITIES

Cost Allocation

All costs of this project are allocated to flood control. They are shown below.

Project Cost	$52,885,000
Annual Charges	$ 4,260,000

Cost Apportionment

Table IV-2 summarizes the distribution of costs between Federal and non-Federal interests.

Federal Responsibilities

Same as Plan B.

Non-Federal Responsibilities

Same as Plan B.

PUBLIC VIEWS

Same as Plan B.

PLAN D

PLAN DESCRIPTION

This alternative would consist of the same two local protection projects discussed previously - the Warwick Avenue Local Protection and the Elmwood Avenue Local Protection Projects acting alone.

The protective measures evaluated for the combined Elmwood Avenue - Warwick Avenue area would protect the same area of Warwick (Zones 7, 8 and part of Zone 6) as given in Plan B.

During the reevaluation of all alternatives after the October 1976 public meeting, and the local support that Plan D gathered, more detailed hydrologic data and subsurface exploration information made Plan D significantly different in heights and costs than originally reported. Some portions of the Elmwood Avenue project increased in height by 5 feet. This resulted in a significantly different method necessary to control the interior drainage/runoff. The net affect was a doubling of costs for the Elmwood Avenue portion as well as the taking of several additional homes due to increased dike width. The benefit-to-cost ratio for the Elmwood Avenue segment based upon the most recent damage survey following the January 1979 flood still was below 0.5.

IMPACT ASSESSMENT

The Warwick local protection project would provide a total annual benefit of about $1,450,000. While the local protection project for comparative purposes would protect 150 ownerships that are subject to flooding at the 100-year flood level, it is standard practice to design Corps local protection project in urban areas to the SPF level to avoid the false sense of security that could result from lower levels of protection. The Warwick local protection project would protect 450 ownerships: 9 industrial, 21 commercial and 420 residential.

For comparative purposes only, at the occurence of a 100-year flood event, river stages would be 3 to 6 feet higher than those experienced in the March 1968 flood, and 7 to 15 feet higher than normal river stages. Under SPF conditions, river stages would be 11 to 15 feet higher than those experienced in the March 1968 flood, and 13 to 20 feet higher than normal river stages.

As mentioned under Plan B, social well-being would be expected to increase due to the increased security afforded area residents by the wall and dike systems. Regional development could be expected as a result of additional new land for development which was formerly

subject to flooding. Existing firms could now expand with a high assurance that their investment will not be eliminated due to a flood.

Construction of the project would bring new jobs thus increasing the work force in the area. This, in turn, could result in increased spending throughout the region. Construction activities could result in a higher volume of traffic in the area in addition to creating additional noise and air pollution.

As stated under Plan B, the resultant dike structures depart from the natural state of riverbank but could be constructed and maintained to reflect an aesthetically pleasing manner.

EVALUATION AND TRADE-OFF ANALYSIS

This plan, effectively and efficiently, provides an SPF level of protection to the previously mentioned areas. With no resultant water pollution as was the case in all plans involving the Natick Diversion, the possible environmental impacts on Apponaug Cove and Greenwich Bay are eliminated. As a result, this plan became more acceptable to both the public and municipal and State agencies.

Appraise System of Accounts

NED Objective - The project first cost of Plan D is $15,050,000, the benefits are $1,450,000 and the annual charges are $1,160,000. The purchase of approximately seven homes would be required at the Elmwood site.

EQ Objective - Noise pollution will increase during construction. The walls and dikes of the local protection projects will detract from the natural riverine state.

SWB Objective - There will be an increased sense of security among area residents as a result of the decreased flood threat. However there will be increased traffic near the construction site.

RD Objective - During construction, employment opportunities for skilled and unskilled workers will increase.

Specific Evaluation Criteria

Acceptability - As this plan does not include the Natick Diversion, it was acceptable to both State agencies and affected individuals. The contribution to the project cost by the city of Warwick was opposed.

Completeness - All necessary actions for successful completion of this alternative have been included.

Effectiveness & Efficiency - Yes.

Certainty - High.

Geographic Scope - The local protection project lie entirely within the Pawtuxet Basin.

NED Benefit-to-Cost Ratio - 1.25.

Reversibility - No.

Stability - High.

MITIGATION REQUIREMENTS

There will be some increase in flood stages immediately upstream from the protection projects due to construction of the dike and wall system on one side of the river, at a SPF occurrence the increase will generally be less than one foot. If Big River Reservoir is to be built, and flood control storage included, this increase due to the wall and dike system would be offset by the reservoir.

IMPLEMENTATION RESPONSIBILITIES

Cost Allocation

All costs of this project are allocated to flood control. The costs are shown below.

Project Cost	$15,050,000
Annual Charges	$ 1,160,000

Cost Apportionment

Table IV-2 summarizes the distribution of costs between Federal and non-Federal interests.

Federal Responsibilities

The benefits accuring to the Warwick Avenue Local Protection and the Elmwood Avenue Local Protection Projects would be local in nature and would entail the usual conditions of local cooperation as listed in the following paragraphs of non-Federal responsibilities. The local protection projects would be constructed by the Federal government and upon its completion would be turned over to the city of Warwick

for operation and maintenance. Federal cost involvement beyond this stage would be limited to Federal personnel costs associated with periodic inspection of the project.

While participation in the National Flood Insurance Program would be a local responsibility, there would be attendant responsibilities, those of providing guidance and technical assistance to the local communities. Part of this guidance would include encouragement that all basin communities consider additional land use controls as needed to minimize future adverse runoff effects as the basin becomes more urbanized.

Non-Federal Responsibilities

Several prerequisities as listed in Plan B would be required of the local interests to prevent further encroachment on the flood plain that could reduce the effectiveness of the diversion project.

Local interests would be responsible for implementing the necessary flood plain regulations required by the National Flood Insurance Program, so that all interested parties would be eligible to purchase insurance under the program. Local communities would also be encouraged to implement additional land use controls, such as evaluation and institution of subdivision regulations, building codes, land easements and related measures. In this regard, this would insure against further encroachment of the flood plains as well as guide their development and redevelopment so as to lessen future flood losses.

PUBLIC VIEWS

As Alternative "D" eliminated the Natick Diversion, which was strongly opposed, it was supported by both State agencies and affected individuals. While this alternative was supported on the basis of the flood protection it provides, the contribution to the cost that the city of Warwick would have to make was opposed. This project is local in nature thereby requiring the city to pay for land acquisition in addition to operation and maintenance. The city of Warwick disagreed with this philosophy in that the flooding problems are a result of upstream development and, therefore, should be considered regional in scope. It would require a bond issue or a budgetary line item on the part of the city which in all probability would not pass.

Plan E

PLAN DESCRIPTION

This alternative consists of the provision for flood control storage at the proposed Big River Water Supply Reservoir equivalent to 6 inches of runoff. This alternative was considered a future action measure to be implemented by non-Fedeal interests prior to the initiation of the Big River feasibility report in October 1977. The plan would also consist of a management/regulation of both Scituate and Big River Reservoir to help reduce flood stages by allowing some flood water storage at Scituate. All costs shown in this document and supporting appendices for Big River Reservoir are based on cost updates from a consultant report. For detailed costs on the Big River project, the reader is advised to review the Big River Feasibility Report.

IMPACT ASSESSMENT

Benefits for the flood control increment at Big River are realized in all downstream zones from the confluence of Big River and the South branch down to and including Zone 8. The total annual benefits for all zones combined amounts to over $550,000 excluding any growth.

The project is not justified as a single purpose flood control dam but when considered as a component of the major water supply purpose is justified for flood control when cost-allocated. This section addresses only those impacts associated with the flood control element of the reservoir. Other impacts attributed to water supply are treated in the report on the feasibility of the Big River Reservoir.

The addition of flood control storage at the proposed Big River Reservoir would create some additional minor negative impacts. When these impacts are weighed against those created by the initial water supply impoundments, they are negligible. The significant adverse impacts are as follows: Should the flood control increment ever be filled to capacity, an additional surface area of 120 acres would be inundated.' This is equal to about .2 square miles. The surface area of the filled water supply pool is estimated at 3,250 acres or 5.1 square miles. The flood control element is designed to hold six inches of runoff from the upstream watershed, which is equal to the excess runoff from events larger than a hundred year storm. This is equal to an increased dam height of about 3 feet. Although this would create an increased pool, the State of Rhode Island currently owns over 8,500 acres in the proposed impoundment and its surrounding area. No additional land takings due to the flood control element would be necessary.

The change in groundwater levels due to the additional heights of flood water in the pool are negligible. At the current design levels, there is less than a three foot difference between the water supply and flood control storage levels. As the flood control waters are only temporarily stored, for a maximum of several days, the additional increase in groundwater would be difficult to measure even with extremely porous soils.

Clearing or additional cutting of vegetation due to the flood control increment should not be necessary. The effect on fish and wildlife at the impoundment would be negligible due to the relatively minor additional height of the dam. The effect on cultural resources at the reservoirs is not known at this time but is being investigated for the Big River feasibility report. No road relocation would be required because of the additional height of the flood control pool. At the proposed elevations I-95 would be in the extreme top of the surcharge range. At extremely rare flood events when the water supply pool is filled to capacity some water could appear on the highway surface due to either wave or wind action or as condensate.

The actual construction of the control dam, an earthen dike with a rip-rapped face, would require additional materials, about 80,000 cubic yards; approximately 38,000 yards of random fill, 30,000 yards pervious and the remainder impervious. Additional borrow pits should not be necessary for this relatively minor increased volume. The movement of the materials and its placement would result in either additional track traffic at the site or more likely increased construction time, causing air quality degradation and noise. Some additional erosion problems during construction could result due to the increased material usage but safeguard measures would be employed at the construction site to minimize the downstream effects.

Negative effects downstream are even less than at the impoundment area. As floodflows would be regulated only during peak flow periods, generally several times per year, no change in the river's ecosystem is expected to occur. There should be no effect on downstream fish and wildlife due to flood control at Big River. There, likewise, would be no loss of wetlands due to the incremental impoundment.

Beneficial impacts from the flood control increment are substantial. Damages to existing structures are significantly reduced for all downstream areas. Average annual damages for zones 4 through 8 are reduced as follows for the existing structures; 42, 43, 48, 36, and 29 percent, respectively or an overall reduction of 36 percent. Because of the very high rate of urbanization being experienced in the basin, a trend that is expected to continue in the future, increased runoff from the basin would result in higher flood stages than presently expected to occur. The construction of Big River flood control element would negate all of the projected increases in flood stages and still provide for a slight reduction over today's levels.

Present zoning requirements have almost eliminated development within the one hundred year flood plain. However, new growth is allowed at or above this level even though it could be damaged by a major flood. Big River Reservoir would provide additional safeguards to new as yet unbuilt residences, commercial and industrial firms.

Overall water quality in the lower Pawtuxet River can be expected to improve during periods of high flow as the reduced flood stages would cause less chance of inundation at the three community sewage treatment plants. Also less inundation of low lying homes and subsequent septic tanks, leaching fields or cesspools would result in less coliforms entering the river.

The effect on downstream transportation roads systems would be positive as they too would be subject to less chance of inundation. Effects on social stability of the community would be slightly improved as there would be less chance of flooding, an extremely descriptive social aspect.

The overall economy of the area would be improved. The additional length of construction time or the use of more equipment would mean increased utilization of the local construction industry with subsequent hiring of more local workers. Secondary benefits of the so called multiplier effect would also be evident as the workers have more money to spend local merchants would gain profits and potentially have additional workers. In addition, the flood-prone industrial and commercial firms would be able to operate for longer periods of time without fear of flooding, subsequent clean up costs, and loss of profit. Also the prevention of plant shut-down due to flooding will allow workers to earn their normal wages.

Hydrologic studies performed by the Corps for the Pawtuxet River watershed studies indicate the existing operation at Scituate Reservoir provides a significant modifying effect on flood discharges along the downstream length of river. If the crest elevation were properly maintained in the late winter and early spring months, additional snowmelt runoff storage could be provided. This would result in added flood control benefits along all downstream zones. In order for this to be successful, it is important that watershed runoff not be wasted. This means that the water content of the snowmelt must be high enough to assure sufficient water supply so that the provision for flood control can be made. Therefore, consideration should be given to maintaining the reservoir at a level not to exceed a predetermined rule curve where the rule curve would be based on the existing water content. If the Providence Water Supply Board accepts this concept, the Corps could provide assistance in establishing a representative snow course. The additional flood control storage would produce no negative impacts.

EVALUATION AND TRADE-OFF ANALYSIS

By addition of flood control storage equivalent to 6 inches of runoff from the upstream drainage area, stage reduction would be evident for all downstream reaches along the South Branch and the mainstem Pawtuxet. While the stage reduction is less than 2 feet for the entire range of flooding events, it would have a significant effect on reducing damages.

There are contingencies that must be implemented before a true determination of the value of Big River can be made. The main contingency is the contruction of a water supply detention area in the nearby Pawcatuck Watershed. When and if completed the water would be pumped from this area into Big River for ultimate storage.

Acceptability of the project is high. This is due to both its ability to provide flood control storage and to supplement the regions water supply. No natural valley storage is lost due to dike construction and additional pollution is negated by elimating a diversionary tunnel.

Appraise System Of Accounts

NED Objective - The project first cost of Plan E is $3,930,000, the project benefits are $725,000 and the annual charges are $450,000. This plan will provide an overall reduction in damages of approximately 36%.

EQ Objective - An additional 0.2 square mile will be inundated at the Big River reservoir site. There will be an overall improvement in water quality but air and noise pollution will be present during construction activities.

SWB Objective - There will be an increased sense of security among area residents as a result of the decreased flood threat. During construction there will be increase in traffic near the site.

RD Objective - During construction, employment opportunities will increase and consequently local spending will increase.

Specific Evaluation Criteria

Acceptability - As Big River Reservoir would benefit the entire state it was generally acceptable to everyone.

Completeness - All necessary actions for successful completion of this alternative have been included.

Effectiveness and Efficiency - Yes

Certainty - Medium

Geographic Scope - This plan lies entirely within the Pawtuxet River Basin.

NED Benefit-to-Cost Ratio - 1.60

Reversibility - No

Stability - High

MITIGATION REQUIREMENTS

None

IMPLEMENTATION RESPONSIBILITIES

Cost Allocation

The objective of cost allocation is to apportion the project costs among the purposes served so that all purposes share equitably in the savings realized from multi-purpose construction. In order to obtain equitable distribution, the costs are distributed so that the allocated share of the cost to any purpose will carry at least its separable cost.

The costs of this project are allocated between flood control and water supply. They are shown on the following table.

	Flood Control	Water Supply
LEGISLATED AUTHORITY		
Federal Contribution	$3,930,000	0
Non-Federal Contribution	0	$67,760,000
PROPOSED COST SHARING REQUIREMENTS		
Federal Contribution	$2,947,500	0
Non-Federal Contribution	982,500	67,760,000

Total Project Cost = $71,690,000

These costs are based on updates of a consultants report. For actual costs of the Big River Reservoir project as currently envisioned, consult the separate feasiblity report.

Cost Apportionment

The non-Federal contribution to flood control is based on legislated policy. Also shown are the costs for the proposed cost sharing which state that non-Federal interests will contribute 25 percent of the cost of flood control works. This non-Federal portion consists of 5 percent cash contribution prior to the start of construction from the State with an additional 20 percent contribution from the benefiting communities or other non-Federal interest thereafter. In this case, the total non-Federal contribution of 982,500 (25 percent of 3,930,000) would all come from the State.

Federal Responsibilities

As the flood control benefits to be derived by the Big River Reservoir would be regional in nature, Federal legislation states that this portion would be a total Federal responsibility. Therefore all costs associated with the construction, operation and maintenance would be Federally funded. Participation in the National Flood Insurance Program would be a local responsibility, although there would be attendant responsibilities such as providing guidance and technical assistance to the local communities. However, the proposed policy states that only 75 percent of the costs will be Federal. Both methods are shown above.

Non-Federal Responsibilities

As previously covered, the flood control portion of the Big River Reservoir would be a total Federal responsibility under existing legislation. However, several prerequisites would be required of the local interests to prevent further encroachment on the flood plain that could reduce the effectiveness of the project:

a. Enforcement in all downstream reaches of the 100-year floodplain and the other basic requirements of the National Flood Insurance Program.

b. Publicizing flood plain information in the area concerned and providing this information to zoning, banking and other groups for their guidance and leadership in preventing unwise future development in the flood plains, and in adapting such regulations as may be necessary to insure compatibility between future development and protection levels provided by the project.

c. At least annually, informing affected interests regarding the limitation of the protection afforded by the project.

Local interests would be responsible for implementing the necessary flood plain regulations required by the National Flood Insurance Program, so that all interested parties would be eligible to purchase insurance under the program. Local communities would also be encouraged to implement additional land use controls, such as evaluation and institution of subdivision regulations, building codes, land easements and related measures. In this regard, this would insure against further encroachment of the flood plains as well as guide their development and redevelopment so as to lessen future flood losses.

PUBLIC VIEWS

As Big River Reservoir would benefit not only the residents of Warwick, but the entire State, most agencies, muncipalities, and individuals favored such a proposal. All those concerned realized the Big River Reservoir Project, indentified in past studies as an alternative for solving the anticipated future water supply needs of the Providence Metropolitan Area, offers the potential of reducing flood damages in the Pawtuxet Basin.

Since the additional flood control storage would mean about a 3 foot increase in pool elevation, additional adverse impacts would be minor. Therefore, public views generally addressed those concerned relating to the project as a whole and the water supply aspects of it. Comments regarding the water supply portion, which is the major element of the project have been presented in the Big River Reservoir feasibility report.

PLAN F

PLAN DESCRIPTION

This alternative would constitute the No Action program or, in effect, what would happen to the Pawtuxet Basin in the absence of any Federal flood control involvement. It would assume that the provisions of the National Flood Insurance Program would be met, thus eliminating most of the growth potential within the 100-year flood plain.

IMPACT ASSESSMENT

Without any protection, the communities along the Pawtuxet would continue to face the threats of flooding. As urbanization increases throughout the basin, runoff rates will increase resulting in higher peak discharges and higher floodwaters. This will result in even higher damages to previously flooded areas as well as inundating normally marginally dry areas. Thus new development in upstream communities, located outside of the flood plain, will increase damages in downstream areas even without any new downstream flood plain development. The prognosis is much worse if flood plain development either in upstream or downstream communities is allowed or if the existing natural valley storage areas of the basin are filled in or reduced in size.

Warwick, Cranston and West Warwick are the only basin communities currently enrolled in the regular program of the National Flood Insurance Program. As such, they have established 100-year flood plain zoning. The increased flood threat for these three communities is the most severe. They must adhere to the basic requirements of the program or face even more potential damages.

The monetary losses without any newly constructed flood control structure would be greatest in the following locations: at the Warwick Industrial Park, the Ciba-Geigy complex, the Warwick Mall area, the Jefferson Avenue industrial complex, the Bulova Watch Company, the Wellington Avenue Industrial Park; the Pontiac Print Works, and the Norwood (Belmont) residential area. Because of the upstream increases in runoff rates the 100-year storm by the year 2020 could be almost 2 feet above that which now exists. At these locations, existing annual losses are $750,000, 1990 losses are $982,00 and 2020 losses are $1,333,000. This corresponds to a total increase of 31.5 percent between the base line hydrology and the 1990 conditions, and a 78.5 percent from base line up to 2020 effects.

EVALUATION AND TRADE OFF ANALYSIS

Appraise System of Accounts

NED Objective. Losses would continue along the tributaries and the mainstem of the Pawtuxet River. Participation in the National Flood Insurance program will help minimize future flood losses.

EQ Objective. No effects.

SWB Objective. The threat of flood damages remains.

RD Objectives. No new land would be available for development and compliance with FIA zoning requirements would be necessary.

Specific Evaluation Criteria

Acceptability. This plan does not involve any major changes and would be acceptable.

Completeness. This plan would have to be implemented by local authorities.

Effectiveness and Efficiency. This plan is only as effective as the degree of enforcement of the regulatory measures.

Certainty. Medium

Geographic Scope. This plan is entirely within the Pawtuxet River Basin.

NED Benefit-to-Cost Ratio. Not applicable.

Stability. Medium

MITIGATION REQUIREMENTS

While no direct protection is provided under this plan, future losses can be minimized by adherence to the management requirements of the National Flood Insurance Program. This is a program enabling property owners to buy flood insurance at a reasonable cost. A community qualifies for the program in two separate phases - the emergency and regular programs. The emergency program provides limited amounts of flood insurance while more detailed studies are undertaken to determine the extent and varying degree of flooding throughout the area. With the completion of the flood insurance rate map the community will qualify for the regular program where a second layer of insurance becomes available. At this point the community's flood plain management efforts become more comprehensive.

IMPLEMENTATION RESPONSIBILITIES

Costs

Under the emergency program the amount of coverage available for a single family residence is $35,000 plus $10,000 for contents. When entering the regular program a second layer of coverage becomes available amounting to $150,000 for the structure and $50,000 for contents. Therefore, the total amount available under the first and second layers is $185,000 for the structure of a single family residence and $60,000 for the contents. Coverage differs for other residential structures and small businesses.

Only the first layer of coverage is available under the emergency program. Slightly higher limits of coverage are available for purchase under the emergency program in Hawaii, Alaska, the U.S. Virgin Islands, and Guam. Full coverage is available under the regular program for all structures in the community. New construction and substantial improvements are charged actuarial rates for all coverage while all existing structures are charged actuarial rates for the second layer of coverage and property owners have the option of paying either the subsidized or actuarial rate for the first layer, whichever is lower.

The subsidized rates are $0.25 and $0.35 per $100 of coverage for the structure and contents respectively for single family residences. Actuarial rates are furnished by the FEMA dependent on the type of structure and elevation relative to the base flood

Federal Responsibilities

Flood insurance is required by law to obtain financing for buying, building or improving property located in the HUD identified flood-prone areas of a community where flood insurance is available. The law applies to any mortgage loan, grant or other funding that in any way is Federally connected - either direct financing from a Federal agency or a conventional mortgage from a bank or savings and loan that is regulated or insured by the Federal Government. When a decision must be made as to whether an individual requires flood insurance, it will be made by a Federal agency. It is also the Federal Governments responsibility to establish flood plain management measures.

Non-Federal Responsibilities

Each Governor has designated an agency of State government to coordinate the State's flood insurance program activities. These agencies assist communities in adopting the programs required flood plain management measures which should be implemented by local

authority. These measures include the requirement that all new buildings in the flood plain be elevated or floodproofed beyond certain levels established by the Federal Emergency Management Agency (FEMA). Also, they require building permits for all proposed construction or other development in the community and a review of the permit to assure that sites are reasonably free from flooding. For its flood-prone areas the community must also require proper anchoring of structures, the use of construction materials and methods that will minimize flood damage, adequate drainage for new subdivisions, and the location and design of new or replacement utility systems to prevent flood loss.

Additional standards are required within any designated floodway or coastal high hazard area. A community is encouraged to adopt more comprehensive standards that exceed the Federal minimum requirements.

PUBLIC VIEWS

Throughout the study and at the various public meetings no opposition was raised concerning a program of regulatory measures such as those required within the National Flood Insurance Program. However, because of the continuing hardship imposed on the people of Norwood, the Flood Insurance Program offered no relief from the potential physical and health hazards created in lieu of a physical protection plan. There was little comment regarding the NFIP since the Corps was not the agency that would implement such a program. This is done by FEMA.

Plan G

PLAN DESCRIPTION

This alternative consists of the 21-foot diameter Natick Diversion tunnel and the Warwick Avenue Local Protection. Alternative G is the same as Alternative C except that the Elmwood Avenue Local Protection Works has been dropped from consideration.

IMPACT ASSESSMENT

The total benefits or damages prevented under this plan are shown on Table IV-2. As was the case under Plan "B", most of the residual losses would occur in the Cranston portions of zones 4B, 6, 7 and 8 but to a slightly higher degree due to lower flow carrying capability of the 21-foot diameter tunnel as opposed to the 30-foot diameter tunnel. The Elmwood Avenue area would experience stage reductions although reoccurring losses can still be expected.

Those impacts attributed to regional development due to construction of this project are the same as those discussed previously under the other plans which included combinations of a diversionary tunnel and local protection projects. Increased social well-being can also be expected as a result of the added flood protection. Environmental impacts connected with this tunnel are the same as the ones covered in Plan A.

EVALUATION AND TRADE-OFF ANALYSIS

As this plan involves the Natick Diversion, its acceptability is low. Water quality, air quality, and other environmental factors contributed to this lack of acceptance.

The plan provides an SPF level of protection to the Warwick Industrial Park. The 21-foot diameter tunnel reduces flood stages as effectively as the 30-foot diameter tunnel up to the 100-year flood. At a 500-year event or 0.2 per cent chance of occurrance flood, reductions in stage are significantly higher using a 30-foot diameter diversion tunnel.

Appraise System Of Accounts

NED Objective - The project first cost of Plan G is $50,020,000, the benefits are $4,303,000 and the annual charges are $4,050,000. An undetermined amount of capitol would be lost due to a reduction in shellfishing.

EQ Objective - Same as Plan A

SWB Objective - Same as Plan A

RD Objective - Same as Plan A

Specific Evaluation Criteria

Acceptability - No, same as Plan A

Completeness - Yes

Effectiveness and Efficiency - Same as Plan A

Certainty - Low

Geographic Scope - Same as Plan A

NED Benefit-to-Cost Ratio - 1.06

Stability - Low

Reversibility - No

MITIGATION REQUIREMENTS

Same as Plan B

IMPLEMENTATION RESPONSIBILITIES

Cost Allocation

All costs associated with this project are to be allocated to flood control. The cost of this project is shown below.

Project Cost	$50,015,000
Annual Charges	$ 4,050,000

Cost Apportionment

Cost apportionment between Federal and non-Federal interests for the plan of improvements is based on Federal legislative and administrative policies governing flood control management programs. Summation of project costs together with project investment and annual charges apportioned among Federal and non-Federal interest is shown on Table IV-2.

Federal Responsibilities

As the flood control benefits to be derived by the Natick Diversion would accrue to three municipalities, namely, the town of West Warwick and the cities of Cranston and Warwick, the project would be regional in character and wholly Federal under present existing legislation. In this regard, all costs associated with construction, operation and maintenance of the diversion project would be Federally funded. The diversion project would be operated and maintained by the Federal Government.

The benefits accruing to the Warwick Avenue Local Protection would be local in nature and would entail the ususal conditions of local cooperation as listed in the following paragraphs on non-Federal responsibilities. The local protection project would be constructed by the Federal Government and upon its completion would be turned over to the city of Warwick for operation and maintenance. Federal cost involvement beyond this stage would be limited to Federal personnel cost associated with periodic inspection of the project.

While participation in the National Flood Insurance Program would be a local responsibility, there would be attendant responsibilities, those of providing guidance and technical assistance to the local communities. Part of this guidance would include encouragement that all basin communities consider additional land use controls as needed to minimize future adverse runoff effects as the basin becomes more urbanized.

<u>Non-Federal Responsibilities</u>

Same as Plan B.

PUBLIC VIEWS

Same as Plan B.

Plan H

PLAN DESCRIPTION

The plan is fundamentally the same as the two local protection projects described under Plan D, but at different design conditions, and this plan includes the multi-use Big River Reservoir complex if eventually found feasible and environmentally acceptable. As the design of the reservoir and its operation would be governed by the Corps of Engineers, flood control storages can be carefully regulated and/or controlled.

IMPACT ASSESSMENT

As mentioned in previous plans involving these measures, Standard Project Flood protection would be afforded the Warwick and Elmwood Avenue areas. Minor adverse impacts resulting from construction such as increased traffic, noise, and air pollution could result as mentioned previously. Also, the dike structures depart from the natural state of the river bank. Previously stated positive impacts on regional development, social well being and increase employment and work force would result from this project.

EVALUATION AND TRADE-OFF ANALYSIS

As a result of the foundations and materials investigations and the relatively small reduction afforded to the local protection areas by flood control storage at Big River Reservoir in comparison to the diversion, the heights of the two local protection measures would have to increase. The overall effect on the Warwick Avenue Local Protection would remain about the same as with the levels considered under Plan D. The significant change occurs in the Elmwood area where the reanalysis indicated that additional riverside berms in the order of 20 feet wide will be required to stabilize the dike. In addition, the reductions afforded under the initial scheme of Plan D were not as great as with the recalculated values mainly because of the tidal influence. Also the costs of the interior drainage facilities increased significantly.

The Elmwood Avenue area in Warwick would cost, at a minimum, six million with lands and damages updated to present figures. As the protected area is mainly residential homes, the level of protection must approach a Standard Project Flood. At that level there are approximately 85 homes and 10 commercial firms that would receive damages. At the hundred year event about 70 homes and 8 commercial concerns would receive damages. Only one of these commercial firm's losses are significant, but in terms of annual damages are relatively minor. However, approximately 10 homes would require relocation because of the dike alignment. Considering the high cost to protect mainly residential structures, the average home would cost in excess of $75,000 each to protect.

Few, if any, of the homes in the area even with the maximum relocation assistance provisions added on, are worth the amount cited. Even though the area warrants some form of protection measure, a local protection project would far exceed the costs even with potential environmental and social trade-offs.

Appraise System Of Accounts

NED Objective - The project first cost of Plan H is $22,030,000, the benefts are $2,001,000 and the annual charges are $1,772,600. The purchase of approximately seven homes would be required at the Elmwood site.

EQ Objective - Same as Plan D - Noise pollution will increase during construction. The walls and dikes of the local protection projects will detract from the natural riverine state.

SWB Objective - Same as Plan D - There will be an increased sense of security among area residents. Seven homes will be relocated.

RD Objective - Same as Plan D - Employment opportunities will inrease during construction.

Specific Evaluation Criteria

Acceptability - Yes

Completeness - Yes

Effectiveness and Efficiency - Yes

Certainty - Medium

Geographic Scope - This plan is entirely within the Pawtuxet River Basin.

NED Benefit-to-Cost Ratio - 1.13

Reversibility - No

Stability - High

MITIGATION REQUIREMENTS

Same as Plan D

IMPLEMENTATION RESPONSIBILITIES

Cost Allocation

All costs are allocated to flood control. This cost for the alternative is as follows.

Project Costs

Warwick and Elmwood Avenue Local Protection Project	$18,100,000
Separable Flood Control Cost of Big River	3,930,000
Total	$22,030,000

Cost Apportionment

Cost apportionment between Federal and non-Federal interests is based upon legislative and management policies pertaining to flood control management program. The flood control element of the Big River Reservoir is considered regional. Therefore it will be Federally funded. According to legislation the local protection projects would be built by the Federal Government. The costs of lands, easements, rights-of-way, and relocation in addition to operation and maintenance would be local responsibilities. These costs are summarized and displayed in Table IV-2.

Federal Responsibilities

As previously mentioned, Big River Reservoir would be a total Federal responsibility. Participation in the National Flood Insurance Program would be a local responsibility, although the Federal Government would provide guidance and technical assistance as an attendant responsibility.

Non Federal Responsibilities

Same as Plan D

PUBLIC VIEWS

The main deterrent to this plan of action was the high costs involved in operating and maintaining the local protection projects which would be a burden to the city of Warwick. City officials claimed that the cause of the flooding problems in their area was due to upstream development and that they (the city) should not have to pay the consequences when others knowingly encroached on the flood plain. They cited that a bond issue or budgetary line item would be needed in order to fund the project. In all likelihood, neither would be passed.

PLAN I

PLAN DESCRIPTION

This plan would consist of the multi-purpose Big River Reservoir, the Warwick Avenue Local Protection Project and a proposal called the Norwood Land Bank. The Norwood Land Bank would involve the purchase of the most flood-prone homes in the Norwood Peninsula (east of Elmwood Avenue) by Federal interest. At present, 40 homes would be bought. The same nonstructural alternatives as considered under other plans would also be applicable to this alternative. These 40 homes have first floor elevations less than the one hundred year flood as modified by Big River, and are all contiguous.

The evaluations of the Warwick Avenue Local Protection would be identical to those considered under the previous alternative. The difference is that the consideration for a local protection project for Elmwood Avenue has been replaced by a proposal for outright purchase of homes. As with the previous alternative, Big River would be planned, designed and if economically justified and environmentally acceptable built by the Corps of Engineers.

In the event that Big River Reservoir is found to be environmentally unacceptable, a second option to Plan I is proposed. This option would still include the Norwood land bank and the Warwick Avenue Local Protection Project as the structural elements of the plan. The difference would be the number of homes to be included in the land bank. As the reductions afforded by Big River Reservoir would be no longer possible, the number of homes experiencing first floor flooding at the hundred year flood would increase by 14; thus 54 homes in the Norwood (Belmont) area would receive first floor flooding. All of these homes would be included in this acquisition program.

IMPACT ASSESSMENT

The benefits attributed to the Warwick Avenue Local Protection and Big River Reservoir are essentially the same as those calculated under the previous alternatives. However the benefits for the Norwood Land Bank consist of those described under ER-1105-2-353, and the benefits to Big River Reservoir have been reduced slightly to acount for the elimination of the homes in the Norwood area that would be purchased under the land bank.

Benefits to Big River	$725,000
Benefits to Warwick Avenue	950,000
Benefits to Norwood Land Bank	126,500
TOTAL	$1,801,500

The Warwick Avenue area is primarily a heavily developed industrial area. With construction activities in this area, the possibility exists that some local merchants might lose business as customers would prefer to shop in a less congested area. Under the second option the height of the protective measures would have to be slightly higher, about one foot on the average, if a standard project design criteria is used.

This plan has the least damaging environmental impacts. The additional 3 feet of storage and consequent increase in pool elevation of the Big River Reservoir complex is assumed to have minimal effects. It is to be reemphasized that the impacts mentioned for Big River are applicable only for the additonal flood control increment of approximately 3 feet. (Under the second option Big River Reservoir would not be constructed.)

It does not include the environmental effects of its major use - water supply. The complete impacts of the entire Big River multi-use complex have been described in the draft EIS prepared by this office contained in the interim reported dated July 1980.

The plan when consisting of Big River Reservoir requires the taking of 40 homes in the Norwood area. These homes are highly subject to flooding. Most receive monetary losses to some degree. Every year homeowners have indicated that they object to relocation. All have first floor elevations below the 100-year flood as modified by Big River Reservoir operation. Under the second option 54 homes would be acquired, all with first floor elevations below the 100 year natural levels without Big River Reservoir. A petition was received in April 1979 containing signatures of approximately 30 affected residents giving their approval of the Corps acquisition plan.

After the homes are purchased and removed, the vacant land could be turned into a park system by local interests with significant funding possible by other Federal agencies.

EVALUATION AND TRADE-OFF ANALYSIS

This plan offers protection to the Standard Project Flood level at the Warwick Avenue area mentioned previously. At the Norwood area 40 to 54 homes (with first floor elevations homes within the 100-year flood plain as modified by Big River Reservoir) would be removed thereby eliminating most of the potential for heavy loses. The remaining homes would still be subject to less frequent flooding events or to a minor amount of groundwater flooding occuring at moderate ranged events.

Residents of the Norwood area have had to evacuate their homes in the past. When ordered to evacuate, most are homeless for several days and in some instances considerably longer. This creates a financial burden to those families as the expenses for lodging, meals, and other related costs are not reimbursable under the Flood Insurance Program.

Evacuation also creates a severe safety and health hazard. Electricity is shut off for the area until the water recedes and switch boxes are inspected. The hot water boilers or furnaces also have to be repaired or replaced constantly. The homes in this area are also on septic tank systems. Due to the constantly rising water levels much of the untreated effluent could be going into the Pawtuxet rather than seeping into the ground. This contributes to the degradation of the area's water quality.

Most of the area residents experience annual cellar flooding. Even after floodwaters recede, groundwater levels remain high necessitating the extended use of sump pumps. Some pumps are operative virtually the entire year.

The problems mentioned above would be eliminated by the Norwood Land Bank under either option. This plan has the most favorable Benefit-to-Cost Ratio among the ten alternatives.

Appraise System of Accounts

NED Objective - The project first cost of Plan I, is $16,870,000, the benefits are $1,801,500 and the annual charges are $1,429,300. The outright purchase of approximately 40 homes in the Norwood area is included in this plan.

EQ Objective - Noise pollution will increase during construction. The walls and dikes of the local protection projects will detract from the natural riverine state. The Norwood site will be available for a recreational area.

SWB Objective - Area residents may experience an increased sense of security but the displacement of families in approximately 40 to 54 residences will be necessary.

RD Objective - During construction, employment opportunities for skilled and unskilled workers will increase.

Specific Evaluation Criteria

Acceptability - Yes.

Completeness - Yes.

Effectiveness & Efficiency - This plan is effective and the least costly.

Certainty - Medium.

Geographic Scope - Entirely within the Pawtuxet Basin.

NED Benefit-to-Cost Ratio - 1.26.

Reversibility - No.

Stability - High

MITIGATION REQUIREMENTS

After the homes are purchased and removed, the vacant land could be utilized as a park system by local interests with significant funding possible by other Federal agencies.

IMPLEMENTATION RESPONSIBILITIES

This section discusses the responsibilities and cost apportionment between Federal and non-Federal interests that would be required for implementation of the recommended plan. As formulated, the plan offers an optimum of development geared to a flood management program for satisfying the economic, social and environmental concerns and resolving the flood problems and needs of the basin.

Cost Allocation

All costs of the alternative are allocated to flood control. Only the flood control element of the Big River Reservoir is included here. Separable costs of flood control and water supply of the Big River Reservoir Project are shown under Plan E. The costs of this project are given below. Under the second option, Big River would not be constructed.

Project Cost	$16,870,000
Annual Charges	$ 1,429,300

Cost Apportionment

Under the present legislated cost sharing requirements the entire flood control separable costs of Big River Reservoir will be totally Federally funded, as it provides region wide flood control benefits. The construction costs of the Warwick Local Protection will also be

Federally funded. However, the costs of lands, damages, rights-of-way, operation and maintenance, etc., will be a non-Federal responsibility. The costs of the Norwood Land Bank will also be highly Federal. This policy has been established under Section 73b of the 1974 Water Resources Development Act. A more detailed discussion on cost sharing of the land bank concept is discussed under the section entitled, "Rationale for the Selected Plan."

Using the current policy applied to major water resources projects, a significant change in cost sharing requirements is evident. Twenty percent of the total projects first cost must be borne by the local benefactors of the project and an additional five percent payment in cash be the State of Rhode Island prior to the start of construction. Detailed project costs for Big River are included in the separate feasibility report. As Big River Reservoir protects four downstream communities in varying degrees it has been determined that the State of Rhode Island should be required to pay the 20 percent local share of the reservoir project. Collect a pro-rated reimbursement from the towns in order to guarantee the cost-sharing requirements. The Warwick Local Protection and the Norwood Land Bank will require the 20 percent contributions from the city of Warwick apportionment is shown in Table IV-2.

Federal Responsibilities

As stated previously, using legislated authority local cost sharing benefits derived from the flood control element of the Big River Reservoir would be regional in scope and therefore funded by the Federal Government. Water supply, its major use, would be a local responsibility.

The Warwick Avenue Local Protection project would be built by the Federal Government with appropriate cost sharing, and upon its completion would be turned over to local authority for operation and maintenance. The same holds true for the Norwood Land Bank.

While participation in the National Flood Insurance Program would be a local responsibility, there would be attendant responsibilities, those of providing guidance and technical assistance to the local communities. Part of this guidance would include encouragement that all basin communities consider additional land use controls as needed to minimize future adverse runoff effects as the basin becomes more urbanized.

Non-Federal Responsibilities

The Big River Reservoir would be built by the Federal Government, as mentioned previously. However, upon its completion, it would be

turned over to local authority for operation and maintenance. At present, this authority would be either the Rhode Island State Water Resources Board or the Providence Water Supply Board. A final determination would be made prior to Congressional authorization for project advanced engineering and design.

As the benefits accruing to the Warwick Avenue Local Protection and the Norwood Land Bank would occur principally within Warwick, the projects would entail the conditions of local cooperation in accordance with Section 3 of the Flood Control Act of 1936, as amended, and in conformance with the policy expressed in EM 1120-2-101. Local interests would be required to give assurances satisfactory to the Secretary of the Army that they would:

a. Provide without cost to the United States, all lands, easements, and rights-of-way necessary for construction of the project;

b. Hold and save the United States free from damages due to the construction works;

c. Maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army;

d. Provide, without cost to the United States, all alterations and replacements of existing utilities including bridges, highways, sewers and railroad modifications and relocations other than railroad bridges and their approaches; which may be required for the construction of the project;

e. Prescribed and enforce regulations to prevent encroachment on both the improved and unimproved channel;

f. Prohibit encroachment on project ponding areas and, if the capacity of these areas is impaired, promptly provide substitute ponding capacity or equivalent pumping capacity without cost to the United States; and

g. Comply with the requirement specified in Section 210 and 305 of Public Law 91-646, 91st Congress, approved 2 January 1971, entitled, "Uniform Relocation Assistance and Real Property Policies Act of 1970."

Local interests would be responsible for implementing the necessary flood plain regulations required by the National Flood Insurance Program, so that all interested parties would be eligible to purchase insurance under the program. Local communities would also be encouraged to implement additional land use controls, such as evaluation and institution of subdivision regulations, building

codes, land easements and related measures. In this regard, this would insure against further encroachment of the flood plains as well as guide their development and redevelopment so as to lessen future flood losses.

PUBLIC VIEWS

Big River Reservoir would benefit many of the residents of the State of Rhode Island from its water supply elements. It would also benefit the communities of Coventry, West Warwick, Cranston and Warwick by reducing the flood problems along the south branch of the Pawtuxet River and the mainstem Pawtuxet. Inclusion of flood control storage of Big River has been recommended by many State and local officials during the public involvement phases of this study.

The Warwick Avenue Local Protection Project was advocated by the city of Warwick throughout the study until the cost sharing requirements become evident. Property owners within the limits of the protection scheme have not voiced strong approval for the project, and one of the larger benefactors of the project has objected to its construction.

The Norwood Land Bank concept was explained to local citizens in public workshops held in March 1979.

Prior to March 1979 the residents of Norwood and Warwick officials had not indicated any support of a potential acquisition plan. After suffering flood damages in both 1978 and 1979 and facing the reality that flooding would always be a threat, support of an acquisition plan grew.

Investigation by this office has indicated that residents of the Norwood peninsula are generally in favor of a relocation program. A petition (See Appendix 3) indicating this was received in April 1979. Repeatedly, over the years, families have had to evacuate their homes as floodwaters rose and the threat of health hazards and unsafe conditions increased. The people of the area view this plan as a relief from the continuing ravages of the Pawtuxet River.

PLAN J

PLAN DESCRIPTION

Plan J is a nonstructural plan. Nonstructural measures include floodproofing, relocation, and regulatory measures to minimize flood loss. As regulatory and future action measures are included in previous plans, floodproofing and relocation are addressed here.

Floodproofing consists of those adjustments to structures which are designed or adapted primarily to reduce existing flood damages. These adjustments usually consist of barriers on windows and doors, a watertight membrane surrounding interior walls, and interior drainage control. Many other floodproofing schemes are also possible. Relocation is required when the potential floodwaters exceed the limits of flood proofing, or excessive depths of flooding are anticipated at moderate ranged events.

Through initial screening it was determined that flood problems within zone 1, 2, 3, 4A and 7A are minimal and no further evaluation was required in these zones. Therefore, analysis was concentrated in zones 4 through 8, and the tributary zones.

A computer program was derived to provide an initial screening of the residential structures. The damage figures used in the program were based on past damage surveys performed by this Division for various types of homes, and the depth damage curves developed by the FEMA. Literature search plus in-house expertise have resulted in the following list of criteria that were used in this program. The criteria applied in this flood proofing program has been previously described in Chapter III on page 11.

IMPACT ASSESSMENT

At the Standard Project Flood level, approximately 616 structures, equivalent to 33 percent of the total number of structures located in the SPF flood area, would have to be relocated. Eighty-three of these structures represent commercial or industrial establishments employing in excess of 5,700 people. At the 100-year flood level, approximately 26 structures would have to be relocated, of which 14 are commercial or industrial firms employing about 2,500 people.

EVALUATION AND TRADE-OFF ANALYSIS

It is evident from the figures shown in Table III-2 where the benefit to cost ratios for the 100-year flood and the Standard Project Flood are 0.10 and 0.04, respectively, that this alternative as a total system is not economically feasible. While it would allow portions of riverbank to be converted to a greenbelt area, the social ramifications would be significant as about 14 industrial and commercial establishments would have to be relocated, resulting in the direct loss of over 2,500 jobs. In addition, about 65 homes would have to be raised or relocated. At the Standard Project Flood analysis, although more theoretical, the losses are much more significant. Table III-2 lists these relocations by major land use category.

The benefit to cost ratio for single structures was also analyzed for those that had high losses and/or low corrective costs. It was determined, with the aid of the computer program for residential structures and individual analysis for nonresidential structures that only a few homes in the basin were considered marginally feasible for flood proofing. It became evident, based on conservative evaluation criteria, that the unreinforced concrete walls would fail at a much lower head differential and the bouyancy effect would necessitate construction of much thicker basement slabs (about 20 inches thick as opposed to the usual 4 inches).

Appraise System of Accounts

NED Objective - The project first cost of Plan J is $324,000,000, the project benefits are $3,120,000 and the annual charges are $26,143,000.

EQ Objective - Not applicable.

SWB Objection - While there would be an increased sense of security for residents, approximately 26 relocations owould be required at the 100-year flood level of protection or 616 relocations at the SPF level.

RD Objective - A direct loss of jobs would result due to relocations.

Specific Evaluation Criteria

Acceptability - Some

Completeness - This plan would require revised zoning and regulatory measures implemented by local authority.

Effectiveness and Efficiency - This plan is not effective in reducing non-physical losses.

Certainty - Medium

Geographic Scope - Entirely within the Pawtuxet Basin.

NED Benefit-to-Cost Ratio - 0.12

Reversibility - Yes

Stability - High

MITIGATION REQUIREMENTS

In addition to being paid for the property acquired by the Government and reasonable moving expenses, a homeowner who is displaced by a project is eligible for a supplemental housing payment up to $15,000 if necessary to assist in the purchase and occupancy of a comparable

decent, safe, and sanitary home. Specific requirements must be met to determine the size of this amount.

Tenants displaced may be eligible for payments up to $4,000 based on other criteria.

IMPLEMENTATION RESPONSIBILITIES

Cost Allocation

All costs are allocated to flood control. The results of the analysis are tabulated by category and by community category. Tables III-1 and III-2 represent total costs of floodproofing structures in the flood hazard areas under existing conditions. The number of affected structures represent ownerships which could include a complex of structures such as a manufacturing concern or a commercial plaza. Thus, the Warwick Mall and Ciba Geigy are handled as constituting only one structure each. The costs noted in both tables include the costs associated with relocation of structures. Although floodproofing measures would be considered only to the 100-year flood event, costs reflecting the Standard Project Flood condition were derived as a means of demonstrating an order of magnitude.

Cost Apportionment

As stated previously, costs were developed for all structures at two levels of flooding, namely the Standard Project Flood and the 100-year flood. Costs to the non-Federal interests cannot exceed 20 percent of the total project first costs, as specified in Water Resources Development Act, 1974.

Federal Responsibilities

Other than the financial obligations mentioned above, the Federal government would install the floodproofing measures in the affected structures and would provide technical assistance such as to local operation and maintenance of the system. This would include correct installation of flood shields on doors and windows and proper sealing of other openings.

While participation in the National Flood Insurance Program is a local responsibility, the Federal government would provide technical assistance and guidance as attendant responsibilities. This would include encouraging all basin communities to consider additional land use controls and to participate in the flood insurance program.

Non-Federal Responsibilities

The individual homeowner would be responsible for making sure that the floodproofing measures are properly placed in the event of an impending flood. All seals should be made ready and the occupants should be ready to evacuate if the situation warrants such action.

Local communities would be responsible for publicizing flood plain information as well as emergency evacuation information. It would be a local responsibility to discourage any future unwise use of the flood plain.

TABLE IV-1
AFFECTS OF ALTERNATIVES
AT KEY DAMAGE AREAS

		A	B	C	D	E	F	G	H	I	J
Heavy Damage Areas	Warwick Industrial Park	MED	HIGH	HIGH	HIGH	LOW	NONE	HIGH	HIGH	HIGH	NONE[2]
	Ciba-Geigy Complex	MED	MED	L/M	NONE[1]	LOW	NONE	L/M	LOW	LOW	NONE[2]
	Norwood Belmont Area	MED	HIGH	HIGH	HIGH	LOW	NONE	L/M	HIGH	RELOC	NONE[2]
	Bulova Complex	HIGH	HIGH	HIGH	NONE[1]	LOW	NONE	HIGH	LOW	LOW	NONE[2]
	Warwick Mall	HIGH	HIGH	HIGH	NONE[1]	MED	NONE	HIGH	MED	MED	NONE[2]
	Midland Mall	HIGH	HIGH	HIGH	NONE[1]	MED	NONE	HIGH	MED	MED	NONE[2]
Moderate Damage Areas	Wellington Ave. Ind. Pk.	MED	MED	L/M	NONE[1]	LOW	NONE	L/M	LOW	LOW	NONE[2]
	Jefferson Ave. Ind. Pk.	M/H	M/H	MED	NONE[1]	LOW	NONE	MED	LOW	LOW	NONE[2]
	Pontiac Mills Building	HIGH	HIGH	HIGH	NONE[1]	MED	NONE	HIGH	MED	MED	NONE[2]
Other Concerns	Warwick Sew. Trt. Plant	HIGH	HIGH	HIGH	NONE[1]	LOW	NONE	HIGH	LOW	LOW	NONE[2]
	Cranston Sew. Trt. Plant	HIGH	HIGH	M/H	NONE[1]	LOW	NONE	M/H	LOW	LOW	NONE[2]
	W. Warwick Sew. Trt. Plant	HIGH	HIGH	HIGH	NONE[1]	MED	NONE	HIGH	MED	MED	NONE[2]
	Pocasset River	LOW	LOW	LOW	NONE[1]	NONE	NONE	LOW	NONE	NONE	NONE[2]
	Meshanticut Brook	LOW	LOW	LOW	NONE[1]	NONE	NONE	LOW	NONE	NONE	NONE[2]
	Natick Flats	HIGH	HIGH	HIGH	NONE[1]	MED	NONE	HIGH	MED	MED	NONE[2]
	Interstate - Major Roads	HIGH	HIGH	HIGH	NONE[1]	LOW	NONE	HIGH	LOW	LOW	NONE[2]

FOOTNOTES

1 No protection unless Big River Reservoir is built by others - See Plan E.

2 No protection unless structures raised/relocated/floodproofed by others.

TABLE IV-2
ECONOMIC SUMMARY TABLE
DECEMBER 1978 PRICE LEVELS
6-7/8% INTEREST RATE

	Project First Cost	Annual Charge	Federal[1] Share	Non-Federal[2] Share	Total Annual Benefits	Net Benefits	Benefit to Cost Ratio	Annual Residual Losses
A	57,800,000	4,650,000	43,350,000 57,800,000	14,450,000 0	4,042,000	-608,000	.87	1,103,000
B	69,380,000	5,552,000	52,035,000 68,530,000	17,345,000 850,000	5,000,000	-552,000	.90	360,000
C	52,890,000	4,260,000	39,670,000 51,990,000	13,220,000 900,000	4,363,000	103,000	1.03	522,000
D	15,050,000	1,160,000	11,290,000 14,150,000	3,760,000 900,000	1,450,000	290,000	1.25	2,150,000
E	3,930,000[3]	450,000	2,950,000 3,930,000	980,000 0	725,000	275,000	1.60	2,395,000
F	0	0	0	0	0	0	N/A	3,120,000
G	50,020,000	4,050,000	37,520,000 49,770,000	12,530,000 250,000	4,303,000	253,000	1.06	532,000
H	22,030,000	1,770,000	15,885,000 20,230,000	5,295,000 950,000	2,001,000	231,000	1.13	1,499,000
I	16,870,000	1,430,000	12,650,000 16,170,000	4,220,000 700,000	1,801,500	372,200	1.26	1,698,500
J	324,000,000	26,143,000	19,610,000 20,910,000	6,540,000 5,230,000	3,120,000[4]	-23,023,000	.12	0

FOOTNOTES

1 Top Number - 75% of Project Cost - Present Policy
Bottom Number - Former Policy

2 Top Number- 25% Total of Project Cost - Present Policy
Bottom Number - Former Policy

3 Flood Control Costs Only

4 Actual Benefits would be less when ER 1105-2-353 Analysis used on relocated structures.

CHAPTER V

COMPARISON OF DETAILED PLANS

TABLES

PLATES

Comparison of Detailed Plans

Because of the duration of the plan formulation and screening processes, several of the alternatives either lacked economic justification or were not acceptable to local interests. All plans including the Natick Diversion as its major structural element were publically unacceptable due to potential environmental problems and therefore eliminated as candidates for the selected plan. The final benefit to cost ratios for plans involving the Natick Diversion were derived in the Draft Technical Appendix of October 1976, and updated to September 1978. Benefits were formulated using guidelines of ER 1105-2-351 dated 13 June 1975.

The riverine environmental quality would be enhanced by alternatives A, B, C, and G. There are, however, potential harmful effects of the diversion which could be felt in Greenwich Bay during a diversion (the major reason why it was found unacceptable). The impacted medium in most instances would be early life stages, i.e., eggs and larvae, and the affected area would be dependent upon the amount and duration of the diversion event, and the particular time of the year. As the rate of the diversion increases above that of a 15-year event, some mortality of first year and older adults of most species would be probable. It is important to note that there is a fairly high uncertainty associated with this statement. This is attributable to the fact that this portion of the analysis was derived from a mathematical model that assumed worst possible conditions such as complete mixing of the fresh water discharge with the saline water of Apponaug Cove and Greenwich Bay, no turbulence at the outlet site which in practice would aid in dispersing the discharge, and that existing water quality data for the Pawtuxet will not improve by the time the diversion would have been operative (1985) as originally assumed in the draft survey report. The latter is of significance only for coliform data which could affect closing of the shellfish beds in Greenwich Bay, both during and after a diversion.

The remainder of the adverse impacts for environmental quality would occur during the construction phases for any of the structural plans presented in the system of accounts. The key adverse impacts would be felt by the transportation system and air quality. With construction of a diversion tunnel, significant truck traffic would be evident at both the intake and outlet structures. Both areas are serviced by 4-lane highways capable of handling the increased truck traffic, but some traffic delays and congestion would be probable.

Plans D, E, F, H, I and J do not include a diversion scheme. Thus, no degradation to marine life would be evident.

The sites of the local protection projects are serviced by major secondary road systems. The Elmwood Avenue area is primarily residential. Altough it is a major thoroughfare (U.S. Route 1), the increased traffic could pose more significant problems regarding safety and air quality levels. The noise associated with this traffic would probably exceed Federal standards on noise levels in urban areas. The Warwick Avenue area is primarily a heavily developed light to medium industrial-commercial area. With construction activities in the latter area, it would be possible that some local merchants might lose business as customers would prefer to shop in a congestion-free environment.

All displayed structural alternatives have positive impacts under the Social Well-Being account. The impacts are the most favorable for Alternative B (30-foot diameter diversion tunnel and the two Warwick Local Protection projects). They afford the highest security possible against potential flooding although significant relocations would be required. Alternatives B and C would require 7 relocations, D-6, A and G-1 H-approximately 10, and I either 40 or 54. Alternative J would require extensive relocations; over 600 for the SPF level of protection accounting for over 5700 jobs; or 26 for the 100 year protection level, or a loss of 2500 jobs. For the relocations required for Big River Reservoir see the feasibility report for actual numbers. No additional relocations would be required for the flood control storage component.

Although construction in an urban area is normally a negative social impact, analysis by this office of the impacted area did not prove this to be true. The people and establishments adjacent to the proposed walls and dikes are subject to constant flooding and hardships. They generally view the construction activities, i.e., the increased noise, traffic etc., as a short term loss, and in exchange they are gaining a lifetime protection against the flood threats which have constantly interfered with their normal operations.

Under the Regional Development account, all structural measures would have positive impacts. Construction activities would produce many new jobs and increase spending in the area. The industrial and commercial establishments along the river would be afforded a high, if not complete, degree of protection against flooding. This could induce them to expand their operations. As they expand, more permanent type jobs would be created. All of the anticipated land growth or urban factors would conform with the proposed land use and zoning criteria currently available from the affected municipalities.

It is to be reemphasized that the impacts mentioned for Big River are applicable only for the additional flood control increment of about 3 feet. It does not include the environmental effects of its major use

- water supply. The complete impacts of the entire Big River multi-use complex are contained in the Draft EIS contained in the Main Report.

Plan D is no longer feasible because of unfavorable foundation conditions at the Elmwood Avenue site. This resulted in an increase in height for the dike sections, the addition of a stabilization berm and a different method for controlling interior drainage. The Warwick Avenue component remains basically the same. This plan is included in the analysis as it was the compromise alternative that the general public wanted after the October 1977 public meeting. Plan H contains the same elements as Plan D with the exception that Big River Reservoir will be an integral portion of the protection scheme rather than a future action measure to be built by others.

Big River Reservoir is a component of Plans H and I (first option) and as well as the only structural element of Plan E. Thus these three plans all afford the same level of flood protection to downstream areas that do not receive some other form of protection recommended in other portions of the respective alternatives. As such they would all have the same positive and negative impacts associated with Big River.

The Warwick Avenue Local Protection Project is a component of Plan B, C, D, G, H, and I, all at the SPF level of protection. For the schemes in combination with the Division, a slightly lower height of wall and dike would be possible. Essentially these plans all feature the same environmental quality, social well-being and regional development effects.

The Elmwood Avenue Local Protection Project is a component of Plans B, C, D, and H. Because of subsequent foundation investigations only the design considerations of Plan H are accurate. Plans B and C both contain the Natick Diversion which is publicly unacceptable. If either of these plans is recommended significant design modifications for the Elmwood Avenue portion would be required, and this would increase the costs by a minimum of $3 million. Plan D has also been eliminated from further consideration.

The Norwood Land Bank is a component of Plan I only. As such, the impacts associated with it are unique to that plan.

Rationale For Designation of NED Plan

The National Economic Development account reflects increases in the nation's productive output, an output which is partly reflected in a national product and income accounting framework designed to measure the continuing flow of goods and services into direct consumption or investment.

The system plan with the highest net NED benefits is Plan G consisting of a 21-foot diameter Natick diversion tunnel and the Warwick Avenue Local Protection project. Also considered would be the non-structural elements - the flood plain zoning and/or participation in the National Flood Insurance Program - and the future action program - the addition of flood control storage onto the Big River Water Supply reservoir to be built by non-Federal interests. As such, this alternative is called the NED plan and provides the highest degree of protection at the least cost to the largest area.

Rationale For Designation of EQ Plan

This objective reflects society's concern and emphasis for the natural environment and its maintenance and enhancement as a source of present enjoyment and a heritage for future generations. The environment is enhanced by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems in the area and the rest of the nation.

Enhancement of the Norwood (Belmont) area would be possible if the resultant vacant area were turned into a recreational park by local interests. As this plan is the least damaging and has potential for enhancing the environment it is designated as the EQ Plan.

The plan with the least damaging environmental impacts that satisfied the objectives of the study is Plan I. Flood control storage at Big River Reservoir, the Warwick Avenue Local Protection Project, and the Norwood Land Bank, an acquisition program for the purchase of 40 homes. For the purposes of this attachment the impacts of the addition of approximately 3 feet of height to the proposed Big River Reservoir dam is assumed to be negligible. Detailed environmental impacts are evaluated in the draft EIS accompanying the Big River feasibility report. If Big River Reservoir is found to have significant environmental impacts, the EQ plan would then be Plan I, option 2, the Warwick Avenue Local Protection Project and the Norwood Land Bank, an acquisition program for the purchase of 54 homes.

Rationale for the Selected Plan

Plans involving the Natick Diversion were rejected due to a lack of public support from out-of-basin, non-floodplain residents. Therefore Plans A, B, C, and G were dismissed. Plan D is no longer feasible due to a subsequent foundations analysis justification for the Elmwood Avenue Local Protection measures. Plan E, a viable alternative, has limited effectiveness in the Warwick Industrial Park area, and does not provide significant flood stage reduction in the Norwood-Belmont Park residential area adjacent to Elmwood Avenue.

The No Action plan, Plan F, assumes that in the absence of Corps participation local interests would implement successful programs for controlling growth within the flood plains. Also, a planning objective of the study is to provide the greatest possible degree of flood protection to the largest area. Plan F was therefore rejected since it did not provide protection to any area. Plan H, although justified as a system, does not have the last added increment of protection, the Elmwood Avenue Local Protection, justified. The B/C ratio is less than 0.5. Ten of the 54 homes that receive significant damages at a hundred year event would have to be relocated because of the dike's alignment. Plan J is not justified from a NED standpoint. Implementation of this alternative could cause the loss of about 6000 jobs and have other potentially devastating regional development effects.

Table IV-2 is a summary of the 10 alternative plans showing their contribution to the economic and environmental objectives in addition to the social well-being and regional development accounts. Also tabulated are each plan's response to the evaluation criteria specified in ER 1105-2-250. Federal and non-Federal responsibilities required to implement each plan are also given.

Only two alternatives are acceptable. Both have Big River Reservoir as the major flood control measure that provides a degree of protection to the region as a whole. Throughout the course of this study there has been strong legislation and public support for some measure of flood protection at the Elmwood Avenue (Norwood-Pelmont Park) residential area. The local support of its residents has been strong at all meetings and workshops. Because of opposition to the numerous plans providing structural relief to these residents as well as many other flood-prone properties along the mainstem Pawtuxet by out-of-basin residents, this key area warrants some form of protection. The local protection project surrounding this area alone is not economically feasible. However an acquisition program involving the most flood-prone homes was found to be economically feasible and acceptable to the local citizens in lieu of the local protection project.

Under Option 1, the legislated policy contained in Section 73b of the 1974 Water Resources Development Act states that "Where (nonstructural alternatives) . . . are recommended, the non-Federal participation shall be comparable to that for the structural protection but not exceed 20 percent of the project costs." The estimated costs for the non-Federal share of the structural alternatives to the Norwood Land Bank is in excess of $600,000. Table V-1 illustrates the cost estimate for the land bank concept. Under this recommended plan, it has been determined that the legislated policy is applicable to the area above First Avenue, a total of 32 homes. However, due to

TABLE V-1

Preliminary Estimate of Real Estate Costs
Norwood Land Bank

Land & Improvements		
54 Improved Properties		$1,350,000
Contingency (20% of above)		$270,000
		$1,620,000
Relocation Assistance Costs		
36 Owner Occupied Units @ $15,000		$540,000
18 Tenant Occupied Units @ $4,000		$72,000
Acquistion Costs		
54 Private Ownerships @ $3,000		$162,000
		$2,394,000
	called	$2,400,000

For 40 structures, the assumed costs were prorated, with the final cost equal to $1,780,000.

the urbanization of the past two decades in areas outside the corporate limits of Warwick, increased runoff from storm events has made the area south of First Avenue more vulnerable to flooding: Much of the urbanization was due to the construction of I-95 and I-295. To work out a cost sharing formula for 20 percent of the remaining 8 homes would be impractical and assurances could not be guaranteed. Hence, the Federal Government would be responsible for these assurances, as well as all the funds required for the uniform relocation assistance.

Detailed costs for Big River are shown in a separate feasiblity report to which this report is attached . At the present time, it is assumed that the allocated flood control share of the project is approximately $3,961,000. Under current legislative cost-sharing policy the Federal share of the flood control separable costs would be 100 percent, which is $3,961,000. The current administration has proposed several changes in cost-sharing for Federal water resources projects. These changes include a cash contribution from benefiting States of 5 percent ($198,050) of the first costs of construction assigned to flood control and an additional 20 percent ($792,200) non-Federal contribution which may or may not be a cash contribution.

More information regarding division of responsibilities for the proposed multi-purpose reservoir project will be presented in the Big River Reservoir report.

Plan I, the Big River Reservoir in conjunction with the Warwick Avenue Local Protection and the Norwood Land Bank, is the selected plan. Although the Norwood Land Bank element requires the taking of about 40 homes under this option, it has been found that the area residents accept the plan in exchange for elimination of the almost annual flood losses they have suffered in the past resulting from the Pawtuxet River overtopping its banks. After the homes are purchased and razed the vacant land could be turned into a park system by local interests with significant funding possible by other Federal agencies.

Big River Reservoir would benefit not only the residents of the Pawtuxet River Basin but the entire State. With water supply becoming a major concern in Rhode Island, the project would provide the needed supplement in addition to contributing to the solution of the flooding problems on the Pawtuxet River.

In view of the lack of local assurances or public support for the Warwick Avenue Local Protection Project, this element of the selected plan is not recommended for construction. Thus the recommended plan

consists of the additon of flood control storage at the proposed Big River Reservoir (if found acceptable) and the Norwood Land Bank. The selected plan as shown on plate V-1.

Should the Big River multi-use Reservoir Project not be recommended for construction, it is advocated that the second option for the Norwood Land Bank be authorized. This option would call for the acquisition of 54 homes all having a first floor elevation below the naturally occurring 100 year flood. The Warwick Avenue Protection Project would not be a recommendation under this option either. The two options for the Norwood Land Bank are shown on plate V-2.

Thus the final costs for the recommended plan are as follows.

May 1980 Price Levels for the Norwood Land Bank
7-1/8 percent interest rate

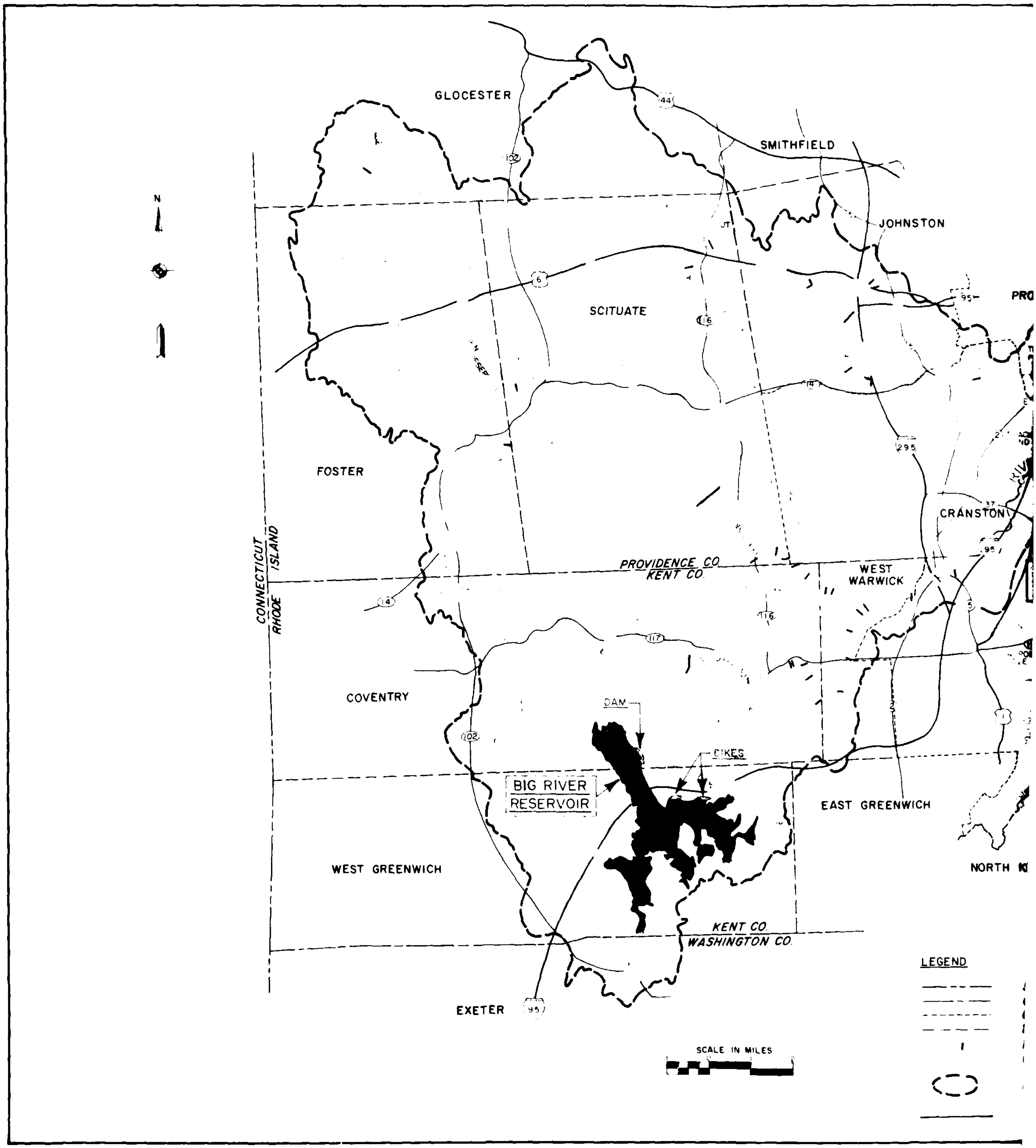
	First Cost	Annual Charge	Benefits
OPTION 1			
Big River Flood Control[1]	3,930,000	500,000	725,000[2]
Norwood Land Bank (40 homes to be acquired)	1,770,000	112,000[3]	126,500
	5,700,000	612,000	851,500
OPTION 2			
Norwood Land Bank (54 homes to acquired)	2,400,000	152,000[3]	170,600

1 - See separate feasibility report for current costs and benefits.

2 - Excludes future benefits all attributable to Big River from 1990-2090 as the Warwick Avenue Protection Project is not recommended for construction.

3 - Excludes relocation assistance costs.

The total cost sharing requirements under these options for both the legislated and the President's proposed cost sharing are shown on Table V-2 and V-3 respectively.


GLOCESTER
SMITHFIELD
JOHNSTON
SCITUATE
FOSTER
CRANSTON
CONNECTICUT
RHODE ISLAND
PROVIDENCE CO.
KENT CO.
WEST WARWICK
COVENTRY
DAM
DIKES
BIG RIVER RESERVOIR
EAST GREENWICH
WEST GREENWICH
NORTH K
KENT CO.
WASHINGTON CO.
EXETER
LEGEND
SCALE IN MILES

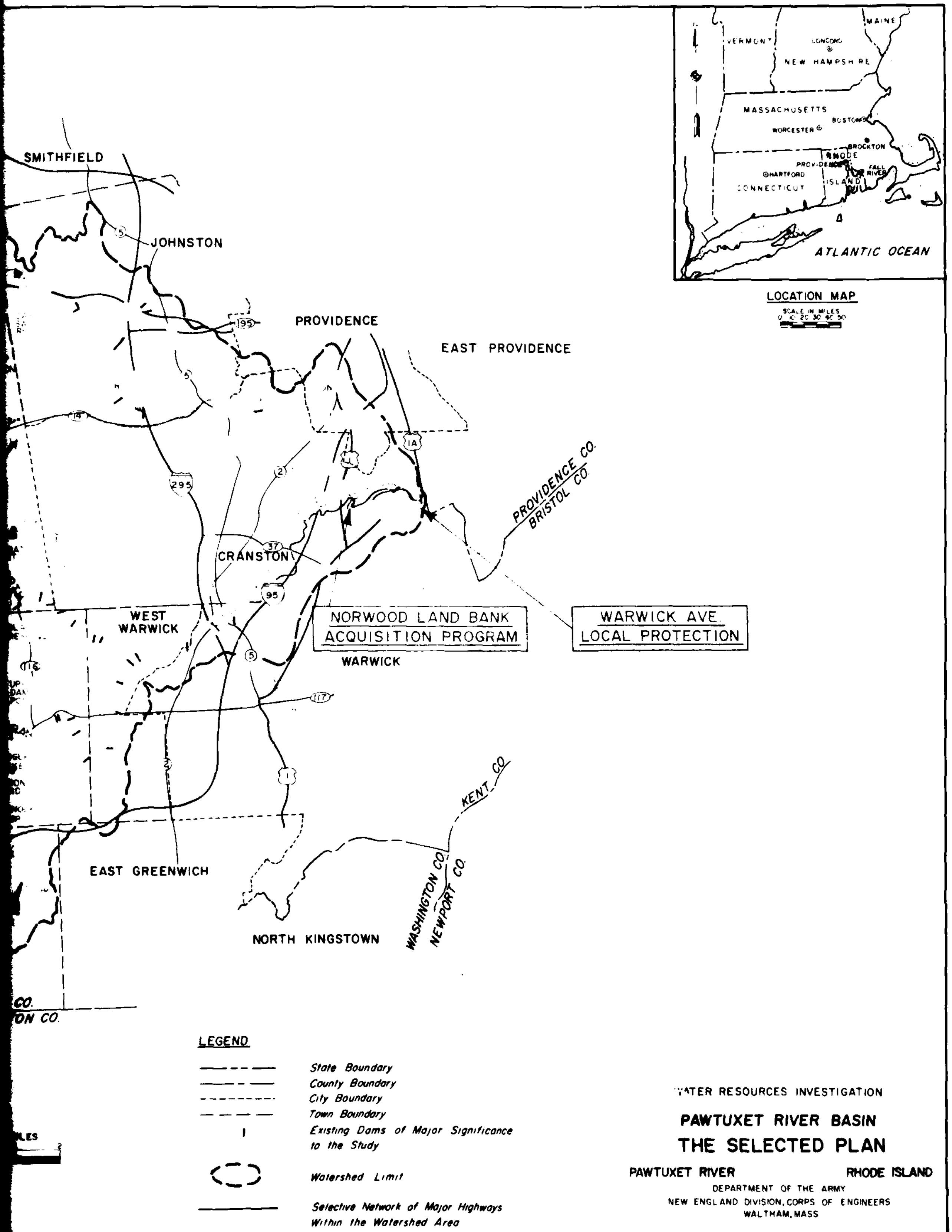
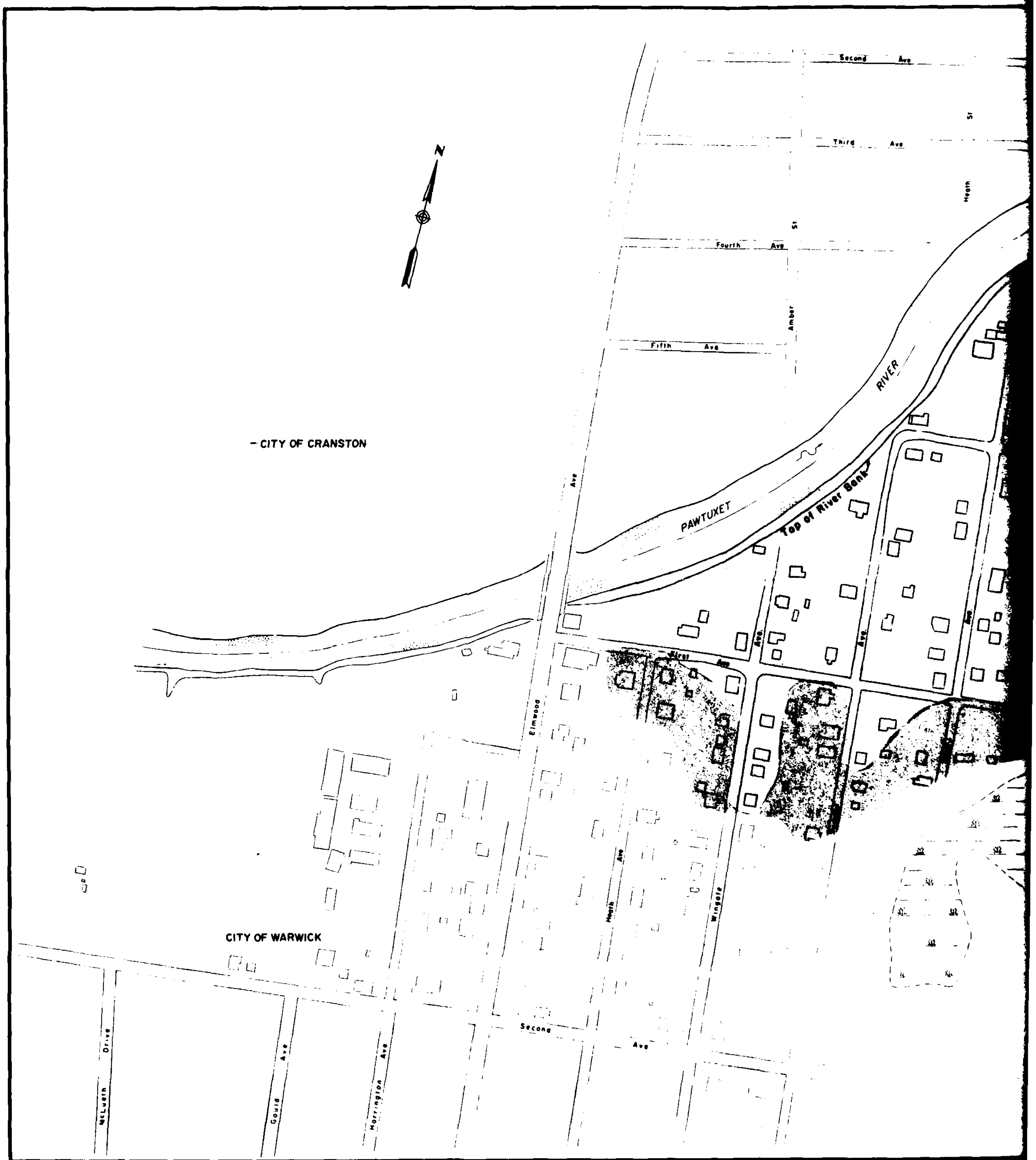
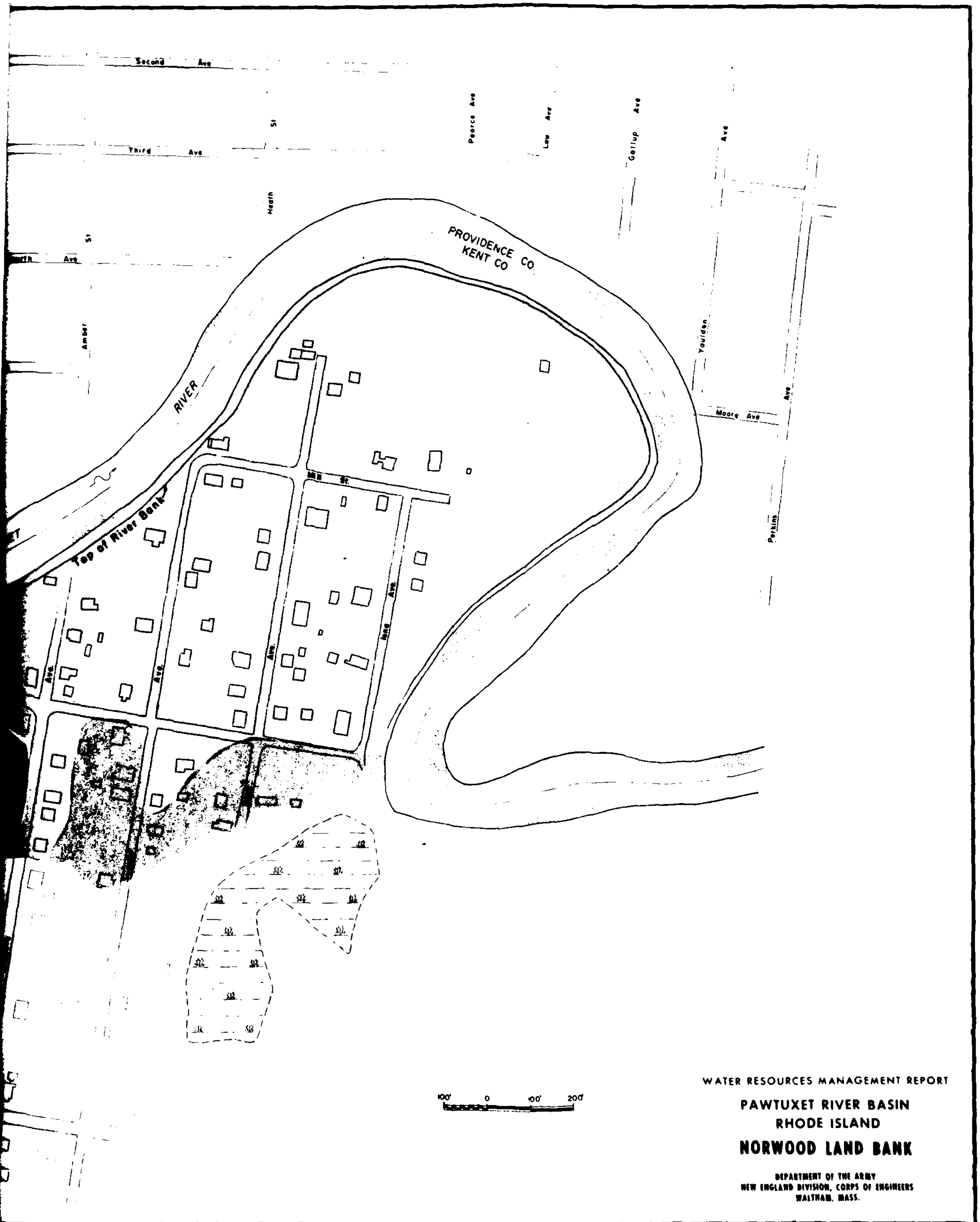

LOCATION MAP
VERMONT
MAINE
CONCORD
NEW HAMPSHIRE
MASSACHUSETTS
BOSTON
WORCESTER
BROCKTON
RHODE ISLAND
PROVIDENCE
HARTFORD
FALL RIVER
CONNECTICUT
ATLANTIC OCEAN
SMITHFIELD
JOHNSTON
PROVIDENCE
EAST PROVIDENCE
PROVIDENCE CO.
BRISTOL CO.
CRANSTON
WEST WARWICK
NORWOOD LAND BANK ACQUISITION PROGRAM
WARWICK AVE. LOCAL PROTECTION
WARWICK
EAST GREENWICH
KENT CO.
WASHINGTON CO.
NEWPORT CO.
NORTH KINGSTOWN
LEGEND
State Boundary
County Boundary
City Boundary
Town Boundary
Existing Dams of Major Significance to the Study
Watershed Limit
Selective Network of Major Highways Within the Watershed Area
WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
THE SELECTED PLAN
PAWTUXET RIVER
RHODE ISLAND
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE V-1



N
Second Ave
Third Ave
Fourth Ave
Fifth Ave
Amber St
Heath St
CITY OF CRANSTON
PAWTUXET RIVER
Top of River Bank
Elmwood Ave
First Ave
Ave
Heath Ave
Wingate
CITY OF WARWICK
Second Ave
McLuein Drive
Gould Ave
Harrington Ave



Second Ave
Third Ave
Heath St
Pearce Ave
Law Ave
Gallup Ave
Amber St
RIVER
PROVIDENCE CO.
KENT CO
Top of River Bank
Mill St.
Moore Ave
Perkins Ave
100' 0 100' 200'
WATER RESOURCES MANAGEMENT REPORT
PAWTUXET RIVER BASIN
RHODE ISLAND
NORWOOD LAND BANK
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE V-2

TABLE V-2
LEGISLATED COST SHARING REQUIREMENTS OF THE RECOMMENDED PLAN

OPTION 1

Federal Share		3,930,000
100% Big River Flood Control		1,136,000
80% 32 Norwood Homes		354,000
100% 8 Norwood Homes		5,420,000
Non-Federal Share		
20% 32 Norwood Homes		280,000
	Total Cost	5,700,000

OPTION 2

Federal Share		
80% 32 Norwood Homes		1,136,000
100% 22 Norwood Homes		984,000
		2,120,000
Non-Federal Share		280,000
20% 32 Norwood Homes		
	Total Cost	2,400,000

TABLE V-3
PROPOSED COST SHARING REQUIREMENTS OF THE RECOMMENDED PLAN

OPTION 1

Federal Share		
75% Big River Flood Control		2,950,000
75% 32 Norwood Homes		1,065,000
95% 8 Norwood Homes		337,000
		4,352,000
State Share		
25% Big River Flood Control		980,000
5% 40 Norwood Homes		88,000
		1,068,000
Other Non-Federal (Local) Share		280,000
30% 32 Norwood Homes		
	Total Cost	5,700,000

OPTION 2

Federal Share		
75% 32 Norwood Homes		1,065,000
95% 22 Norwood Homes		935,000
		2,000,000
State Share		
5% 54 Norwood Homes		120,000
Other Non-Federal (Local) Share		280,000
20% 32 Norwood Homes		
	Total Cost	2,400,000

CHAPTER VI

CONCLUSIONS

The purpose of this report is to develop a plan, acceptable to the local interests, that would alleviate the flooding and associated water resource problems in the Pawtuxet River Basin. The report is submitted in partial compliance with seven Congressional resolutions combined under one resolution adopted by the Committee on Public Works of the United States Senate.

Ten alternatives, involving various combinations of flood control measures, have been presented in this report. Four of these alternatives include the Natick Diversion Tunnel, six include the Warwick Avenue Local Protection Project, and four include the Elmwood Avenue Local Protection Project. Big River Reservoir, with flood control storage, has been included in four alternatives and the Norwood Land Bank in one. A No Action Program and a Non-Structural Plan are two of the ten alternatives presented. Nine of the ten alternatives are effective in significantly reducing flooding and flood losses in the Pawtuxet River Basin.

Numerous meetings concerning the PNB study have been held with Federal, State and local agencies since the initiation of the PNB study. On 3 March 1979, a workshop meeting was held in Warwick, Rhode Island to formally announce plans for the Norwood Land Bank proposal, an acquisition program calling for at that time 32 homes, all located north of First Avenue. As a result of this and subsequent meetings with Norwood residents, a high degree of public acceptance was evident. An acquisition plan involving the now 40 to 54 homes depending upon conditions has been advocated.

All plans' involving the Natick Diversion Tunnel were publically unacceptable, although highly effectively in reducing flood damages. The opposition to these proposals was mainly from out of basin residents in the area of the proposed outlet works in Apponaug Cove. This was chiefly due to the potential for detrimental affects to marine life in the Cove and Greenwich Bay during a diversion of floodwaters. Plan D, the orginally formulated wall and dike system protecting the Warwick Industrial Park and the Norwood residential area, is no longer viable due to subsequent detailed foundation and hydrologic analyses. Plan E flood control storage at Big River Reservoir has been the subject of a separate feasibility study. Costs for the reservoir as shown in this report are based on cost updates of architect/engineer estimates prepared from reports previously submitted to the Rhode Island Water Resources Board. Overall the flood protection provided by this plan is not as effective as the Natick Diversion plans. Althougl. 't does provide a high percentage reduction in losses at the Warwick Industrial Park and the Norwood Residential area, it is not comparable tc the

protection afforded by a local protection project. The Environmental Impacts of Big River Reservoir have been thoroughly discussed in the separate feasiblity report.

Plan H, the reevaluated Warwick Avenue (Warwick Industrial Park) and Elmwood Avenue (Norwood Residential area) local Protection Projects and the Big River Reservoir proposal, although having a benefit-to-cost ratio in excess of unity is not incrementally justified with the Elmwood Avenue portion of the protection project, although socially and environmentally acceptable.

The primarily non-structural alternative Plan J has a significantly lower than unity benefit-to-cost ratio. Although portions of the floodplain could be reverted back to a green belt, making this plan environmentally acceptable the social impacts of losing employment opportunities at all of the relocated facilities totalling well over 2000 jobs is not acceptable. The summary system of accounts Table VI-1 presents all significant impacts and evaluations for all ten plans.

I have reviewed and evaluated in depth in view of the overall public interest, all documents concerning the proposed action and the stated views of the general public. For the reasons outlined above and throughout this report and supporting appendices, I recommend that the compromise alternative, Plan I consisting of construction of the multi-use Big River Reservoir, the Norwood Land Bank proposal and the Warwick Avenue Local Protection Project be authorized. However, because of the lack of the local support from the public and indications that the city of Warwick could not be able to cost-share in the protection project construction, I do not recommend construction of the Warwick Avenue Local Protection Works.

TABLE [illegible]
SUMMARY TABLE

	BASE CONDITION 1979	PLAN A	PLAN B	PLAN C
A. PLAN DESCRIPTION	Significant recent flooding along the tributaries and mainstem, especially at the Warwick Avenue and Elmwood Avenue areas. Considerable development still occurring near the 100-year flood plain and throughout the basin.	30' Diameter Natick Diversion	30' Diameter Natick Diversion with Warwick Avenue Local Protection and Elmwood Avenue Local Protection.	21' Diameter Natick Diversion [illegible] Warwick Avenue Local Protect[illegible] Elmwood Avenue Local Protect[illegible]
B. IMPACT ASSESSMENT				
NED Objective:	a) Losses would continue along tributaries and mainstem and because of urbanization will result in higher annual damages. b) Property values of flood-prone homes and other structures will not appreciate.	Project benefits $4,042,000 Annual Charges $4,650,000 B/C 0.87	Project Benefits $5,000,000 Annual Charges $5,552,000 B/C 0.90	Project Benefits $4,36[illegible] Annual Charges $4,26[illegible] B/C 1.0[illegible]
EQ Objective:	a) Flooding will contribute to water quality degradation, especially at the Warwick and West Warwick sewage treatment plants and from septic tank failures in flood-prone locations. b) Floodplain encroachment in many areas is reducing amount and variety of natural vegetation and wildlife. c) Because of constant flooding aesthetic values of basin will diminish.	a) Undetermined amount of lost capitol due to reduction in shell fishing during diversion of water. b) Reduction in damages, Zones 4-8 of 70%.	a) Same as Plan A-a. b) Reduction in damages, Zones 4-8 of 87%.	a) Same as Plan A-a. b) Reduction in damages; [illegible] of 85%.
SWB Account:	a) Perpetual threat of flooding. b) Numerous Norwood families must be evacuated when flooding occurs. c) Low real estate values in flood-prone neighborhoods.	a) Air pollution and noise pollution will increase during construction. b) Increased coliform counts in Apponaug Cove and Greenwich Bay. c) Reduced salinity during discharges in Apponaug Cove and Greenwich Bay may cause mortality to some aquatic species. d) Intake and outlet structures depart from natural riverine state. e) Disposal of rock spoil.	a) Elimination of oxbow at Warwick Avenue will result in loss of 6.3 acres of Pawtuxet Reservation currently supporting some wildlife and vegetation.	Same as Plan B
RD Account:	a) 8.8% Unemployment rate consistently higher than the national average. b) Underutilization of available industrial and commercial floor space due to threat of inundation. c) Threat of, and actual, flooding has caused several large employers to cease operations resulting in some loss of jobs.	a) Increased sense of security. b) Stigma of tunnel easements. c) Undetermined amount of shellfishing days lost could cause some unemployment. d) Increased traffic at construction site. e) Relocation of one home.	a) Same as Plan A. b) Relocation of 7 homes. c) Loss of a portion of Pawtuxet Reservation. d) Question of ownership for the newly created land at the Warwick Local Protection Project. e) Increased sense of security for the residents of the Belmont Park area.	Same as Plan B
C. PLAN EVALUATION				
1. Contributions to Planning Objectives:	N/A	a) Increased protection could allow for better utilization of existing floor space. b) Increased employment for skilled and unskilled workers during construction. c) Protection project could spur new economic activity.	a) Industrial Park could house more similar type industries without significant site location problems.	Same as Plan B
2. Net Affects:	N/A	a) Provides high degree of protection to lower mainstream reaches.	a) Provides SPF level of protection to Warwick and Elmwood sites. b) High degree of protection afforded to lower mainstream reaches.	a) Provides SPF level of [illegible] to Warwick and Elmwood [illegible] b) Slightly lower degree of protection to mainstream reaches.
3. Plan Response to Associated Evaluation Criteria:	N/A	a) Affected ownerships reduced from 471 to 266 for a 100-year flood. b) Reduced from 1850 to 959 for an SPF event.	a) Affected ownership reduced from 471 to 148 for a 100-year flood. b) Reduced from 1856 to 753 for an SPF event.	Same as Plan B
Acceptability		No	No	No
Completeness		Yes	Yes	Yes
Effectiveness & Efficiency		a) Effective and efficient but pollution standards may be compromised.	a) Effective and efficient but most costly.	a) Less effective than Plan [illegible]
Certainty		Low	Low	Low
Geographic Scope		Flood waters are transferred out of Pawtuxet Basin.	Same as Plan A	Same as Plan A
Reversibility		No	No	No
Stability		Low	Low	High
4. Rankings of Plans	N/A			
NED		8	7	6
EQ		8	10	9
SWB		5	6	7
RD		4	1	2
D. IMPLEMENTATION RESPONSIBILITIES (Present Legislation)	N/A	Diversion - Regional Protection - All costs, maintenance and operation, and lands - 100% Federal.	Diversion - See Plan A; Local Protection Project - City of Warwick provides lands, damages, O&M costs; Construction costs - 100% Federal.	Same as Plan B

*Although Plan I has the greatest BCR, Plan C provides the greatest benefits to the greatest number of people and is therefore the NED Plan.
**As Plan J is too unrealistic, Plan I is the EQ Plan.

TABLE VI-2
SUMMARY TABLE

PLAN B	PLAN C	PLAN D	PLAN E
30' Diameter Natick Diversion with Warwick Avenue Local Protection and Elmwood Avenue Local Protection.	21' Diameter Natick Diversion with Warwick Avenue Local Protection and Elmwood Avenue Local Protection.	Warwick Local Protection and Elmwood Local Protection Projects.	Provision for flood control at Big River Reservoir.
Project Benefits $5,000,000 Annual Charges $5,552,000 B/C 0.90	Project Benefits $4,363,000 Annual Charges $4,260,000 B/C 1.03	Project Benefits $1,450,000 Annual Charges $1,160,000 B/C 1.25	Project Benefits $725,000 Annual Charges $452,000 B/C 1.60
a) Same as Plan A-a. b) Reduction in damages; Zones 4-8 of 87%.	a) Same as Plan A-a. b) Reduction in damages; zones 4-8 of 85%.	a) Local Protection Projects increase flood stages on opposite banks and upstream areas. b) Reduction in damages; Zones 4-8 of 48%.	a) Reduction in damages, Zones 4-8 of 36%.
a) Elimination of oxbow at Warwick Avenue will result in loss of 6.3 acres of Pawtuxet Reservation currently supporting some wildlife and vegetation.	Same as Plan B	Same as Plan B	a) Additional 0.28 sq. mi. will be inundated at reservoir site. b) Construction period will increase slightly.
a) Same as Plan A. b) Relocation of 7 homes. c) Loss of a portion of Pawtuxet Reservation. d) Question of ownership for the newly created land at the Warwick Local Protection Project. e) Increased sense of security for the residents of the Belmont Park area.	Same as Plan B	a) Relocation of 6 homes.	a) Increased sense of security. b) Slight increase in traffic. c) *No additional land taken or* relocation necessary.
a) Industrial Park could house more similar type industries without significant site location problems.	Same as Plan B	Same as Plan B	Same as Plan B
a) Provides SPF level of protection to Warwick and Elmwood sites. b) High degree of protection afforded to lower mainstream reaches.	a) Provides SPF level of protection to Warwick and Elmwood areas. b) Slightly lower degree of protection to mainstream reaches.	a) SPF level of protection at Warwick and Elmwood areas.	a) Significant reduction in flood stages in all downstream reaches.
a) Affected ownership reduced from 471 to 148 for a 100-year flood. b) Reduced from 1856 to 753 for an SPF event.	*Same as Plan B*	a) Protection for 150 ownerships at 100-year level. b) Protection to 450 at SPF.	a) Reduction in damages in all downstream reaches.
No	No	Yes	Yes
Yes	Yes	Yes	Yes
a) Effective and efficient but most costly.	a) Less effective than Plan B.	a) Plan as originally presented is no longer possible due to design changes.	Least costly but also less effective of the two regional protection measures.
Low	Low	High	High
Same as Plan A	Same as Plan A	Entirely within Pawtuxet Basin.	Same as Plan D
No	No	No	No
Low	High	High	High
7	6	3	2
10	9	5	3
6	7	1	4
1	2	7	8
Diversion - See *Plan A; Local* Protection Project - City of Warwick provides lands, damages, O&M costs; Construction costs - 100% Federal.	Same as Plan B	See Plan B for local protection projects.	Flood Control Reservoir provides regional benefits - all costs- 100% Federal.

the NED Plan.

TABLE VI-1
SUMMARY TABLE

	BASE CONDITION 1979	PLAN F	PLAN G	PLAN H	
A. PLAN DESCRIPTION	Significant recent flooding along the tributaries and mainstem, especially at the Warwick Avenue and Elmwood Avenue areas. Considerable development still occurring near the 100-year flood plain and throughout the basin.	No Action	21' Diameter Natick Diversion and Warwick Avenue Local Protection Project.	Big River Reservoir and Warwick Avenue and Elmwood Avenue Local Protection Projects.	Big Ave Non
B. IMPACT ASSESSMENT					
NED Objective:	a) Losses would continue along tributaries and mainstem and because of urbanization will result in higher annual damages. b) Property values of flood-prone homes and other structures will not appreciate.	a) Losses would continue along the tributaries and mainstem. b) Participation in National Flood Insurance Program.	Project Benefits $4,303,000 Annual Charges $4,050,000 B/C 1.06 a) Same as Plan A b) Reduction in damaged in Zones 4-8 of 60%.	Project Benefits $2,000,000 Annual Charges $1,770,000 B/C 1.13 a) Purchase of approximately 7 homes at Elmwood Site. b) Reduction in damages, Zones 4-8 of 84%.	a) b)
EQ Objective:	a) Flooding will contribute to water quality degradation, especially at the Warwick and West Warwick sewage treatment plants and from septic tank failures in flood-prone locations. b) Floodplain encroachment in many areas is reducing amount and variety of natural vegetation and wildlife. c) Because of constant flooding aesthetic values of basin will diminish.	No	Same as Plan A	Same as Plan D	a) b)
SWB Account:	a) Perpetual threat of flooding. b) Numerous Norwood families must be evacuated when flooding occurs. c) Low real estate values in flood-prone neighborhoods.	a) Flood threat remains. b) Real estate transactions of floodplain property would be more difficult. c) Reduced property values.	Same as Plan A	a) Increased sense of security. b) Increased traffic near construction site. c) Relocation of 6 homes.	a) b) c)
RD Account:	a) 8.8% Unemployment rate consistently higher than the national average. b) Underutilization of available industrial and commercial floor space due to threat of inundation. c) Threat of, and actual, flooding has caused several large employers to cease operations resulting in some loss of jobs.	a) Increased flood threat may result in relocation of several floodprone industries. b) Decrease in the amount of useable floor space.	Same as Plan A	Same as Plan D	
C. PLAN EVALUATION					
1. Contributions to Planning Objectives:	N/A	Limits the extent of future damages through regulatory measures.	a) Provides SPF level of protection to Warwick Avenue area. b) Slightly lower protection to lower mainstem than with the 30' diameter tunnel.	a) SPF protection to Warwick and Elmwood areas. b) Additional stage reductions downstream of reservoir.	a) b) c)
2. Net Affects:	N/A	Increase in existing losses due to increased flood stages resulting from urbanization.	Provides a high degree of flood protection.	Same as Plan D	a) b)
3. Plan Response to Associated Evaluation Criteria:	N/A				
Acceptability		Yes	No	Yes	
Completeness		No, this plan would be implemented by local authority.	Yes	Yes	
Effectiveness & Efficiency		Only to the degree of enforcement of regulatory measures.	Less effective than Plan C.	Effective and Efficient	The eco
Certainty		Medium	Low	Medium	
Geographic Scope		Same as Plan D	Same as Plan A	Same as Plan D	
Reversibility		Yes	No	No	
Stability		Medium	Low	High	
4. Rankings of Plans	N/A				
NED		NA	5	4	
EQ		4	7	6	
SWB		9	8	2	
RD		9	3	5	
D. IMPLEMENTATION RESPONSIBILITIES (Present Legislation)	N/A	N/A	See Plan B	Essentially the same as Plan B.	a) b) c)

*Although Plan I has the greatest BCR, Plan G provides the greatest benefits to the greatest number of people and is therefore the NED Plan.
**As Plan J is too unrealistic, Plan I is the EQ Plan.

	PLAN H	PLAN I	PLAN J
Diversion and l Protection	Big River Reservoir and Warwick Avenue and Elmwood Avenue Local Protection Projects.	Big River Reservoir and Warwick Avenue Local Proteciton Project and Norwood Land Bank.	Non-Structural
s $4,303,000 $4,050,000 1.06 aged in Zones 4-	Project Benefits $2,000,000 Annual Charges $1,770,000 B/C 1.13 a) Purchase of approximately 7 homes at Elmwood Site. b) Reduction in damages, Zones 4-8 of 84%.	Project Benefits $1,801,500 Annual Charges $1,429,300 B/C 1.26 a) Purchase of 40-54 homes in Norwood area (Elmwood Avenue). b) Reduction in damages, Zones 4-8 of 70%.	Project Benefits $3,120,000 Annual Charges $26,143,000 B/C 0.12
Plan A	Same as Plan D	a) Same as Plan D. b) Recreational site possible at Norwood.	None
Plan A	a) Increased sense of security. b) Increased traffic near construction site. c) Relocation of 6 homes.	a) Increased sense of security. b) Increased traffic near site. c) Displacement of residents of 40-54 homes.	a) Increased sense of security. b) Approximately 26 reloctions required at 100-year flood level - loss of 2500 jobs. c) Approximately 616 relocations required at SPF level - loss of approximately 6000 jobs.
Plan A	Same as Plan D	Same as Plan D	Direct loss of jobs due to relocation.
vel of protection e area. protection to than with the 30' l.	a) SPF protection to Warwick and Elmwood areas. b) Additional stage reductions downstream of reservoir.	a) SPF protection to Warwick Avenue area. b) Eliminates continuing flood damages to homes at Norwood. c) Reduces flood stages downstream of reservoir.	Reduces flood damages to a degree.
gree of flood	Same as Plan D	a) Approx. the same as Plan D. b) Portions of the flood plain would revert to a green belt free from development.	Non-physical losses would remain.
	Yes	Yes	Some
	Yes	Yes	Yes
Plan C.	Effective and Efficient	The plan is effective and the most economically efficient.	Not effective in reducting non-physical losses.
	Medium	Medium	Medium
Plan A	Same as Plan D	Same as Plan D	Same as Plan D
	No	No	Yes
	High	High	High
3	4	1*	9
7	6	2	1**
8	2	3	10
3	5	6	10
Plan B	Essentially the same as Plan B.	a) All reservoir costs would be 100% Federal. b) Local protection project construction costs - 100% Federal. c) Land Bank - essentially 80% Federal, 20% Non-Federal (City of Warwick).	80% Federal 20% Non-Federal

ENVIRONMENTAL IMPACT STATEMENT

The draft EIS for the Pawtuxet River Interim Flood Control Report was released on 29 June 1976. The preferred plan presented in the DEIS to provide flood control was a combination of the Natick Diversion and dikes at the Warwick Avenue Industrial Park and at the Elmwood Avenue residential area. Also proposed was flood control storage at the Big River Reservoir if that project was ever built. During the public comment period and subsequent public meetings, heavy opposition was developed particularly to the Natick Diversion. The concern was that the Diversion although providing near complete flood control would have serious impacts upon the commercial shellfishing at the flood water outlet area in Greenwich Bay. Consequently, local interests and political figures voiced considerable opposition to the proposal. Therefore, due to lack of local support, further consideration of any diversion scheme would not be recommended.

Without the Diversion the two dikes would have to be built to a larger scale. In subsequent planning and coordination with local interests, no local sponsor came forth for the Warwick Avenue Dike. Consequently although economically feasible, the project is not recommended.

Review of the Elmwood Avenue flooding area indicates that there is adequate justification for acquisition of properties affected by the 100 year flood. Through public involvement activities with local interests, both those whose homes would be bought and local officials, it has been determined that this proposal is preferred and is recommended as a measure to eliminate flood damage. There are no significant impacts related with this proposal.

The original DEIS allowed for the various decisions as now presented to be developed. The final proposal although not resulting in the flood reduction as originally desired does result in a plan with local support and lesser impacts to the environment. Therefore, it is planned to incorporate the refined plan into the final EIS and address in general the comments received in the open comment period and the public involvement activity which has taken place since that time, resulting in the new preferred plan. It is not considered necessary to supplement the DEIS inasmuch as no important or significant impacts are related with the new proposal. The proposed final Environmental Impact Statement follows.

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PREFACE

The Draft EIS for the Pawtuxet River Watershed Report was issued in September, 1976. At that time one element in the selected plan included diverting water from the Pawtuxet River through a tunnel (Natick Diversion) to Apponaug Cove. Great opposition to this one element was voiced at a public meeting on October 18, 1976, primarily because of the cost involved and the potential adverse impact to the marine environment of Apponaug Cove. The Corps, though, was still asked to continue with the study by evaluating other alternatives in greater detail.

Alternative D, consisting of the Warwick Local Protection Project and the Future Action of the Big River Reservoir, was given support by the public at the late-stage public meeting in May, 1977. After detailed hydrological analysis it was determined that the dike system at Elmwood Avenue (Norwood) and Warwick Avenue would have to be raised three feet to provide for Standard Project Flood (S.P.F.) protection. The biggest area of concern was in the Norwood section of Warwick. The cost to raise the dike to a higher elevation proved to be not economically feasible. Another alternative that was then developed was to buy the homes in the flood prone area (Norwood Land Bank). This plan was discussed with local officials and residents at a workshop meeting on March 3, 1979.

To summarize, the survey process for the Pawtuxet River Watershed Report has resulted in the following selected plan (the entire survey process is described in Section 6):

1. Warwick Avenue Local Protection Project

2. Norwood Land Bank

3. Flood Control Storage at the Big River Reservoir

However, due to the lack of a local sponsor the Warwick Local Protection Project element of the selected plan cannot be recommended for Federal implementation.

1.00 PROJECT DESCRIPTION

1.01 Name and Location. The Pawtuxet River watershed (Figure I-1) lies in the central portion of Rhode Island. It is flanked by four major watersheds: the Blackstone and Woonasquatucket River Basins to the north, the local drainage to Narragansett Bay to the southeast, the Pawcatuck River Basin to the southwest, and the Thames River Basin to the west. The Pawtuxet River is formed by the junction of its two principal tributaries, the North and South Branches, at Riverpoint in the town of West Warwick. It flows generally to the east and empties into Pawtuxet Cove on the Providence River in the upper reach of Narragansett Bay.

1.02 Objective. The primary objective of the Pawtuxet River Watershed Study is to formulate a well-balanced flood management program.

1.03 Authority. The study is in partial compliance with seven Congressional resolutions combined under one resolve adopted by the Committees on Public Works of the United States Senate and the House of Representatives. These resolutions authorized the Pawcatuck River and Narragansett Bay Drainage Basins (PNB) Study, which includes the Pawtuxet River Basin. Three resolutions pertained to the Pawtuxet River Basin. Two resolutions, one adopted 29 March 1968 and the other 10 July 1968, requested review of the Narragansett Bay volume of the New England - New York Inter-Agency Committee (NENYIAC) report. The third resolution, adopted 2 February 1970, requested whether improvements for flood control and other purposes were warranted along the Pawtuxet River, Pocasset River, and Meshanticut Brook in the vicinity of Cranston.

1.04 Dimensions and Purposes of the Selected Plan. To satisfy the objectives of the study, a plan has been selected which entails a combination of regulatory and corrective measures involving both nonstructural and structural components. The selected plan, Plan I, is shown on Figure I-2.

1.05 A non-structural corrective measure proposed is the Norwood Land Bank. It provides for the eventual purchase of 40 homes at fair market value plus relocation assistance by the time the structural elements of selected plan are operable.

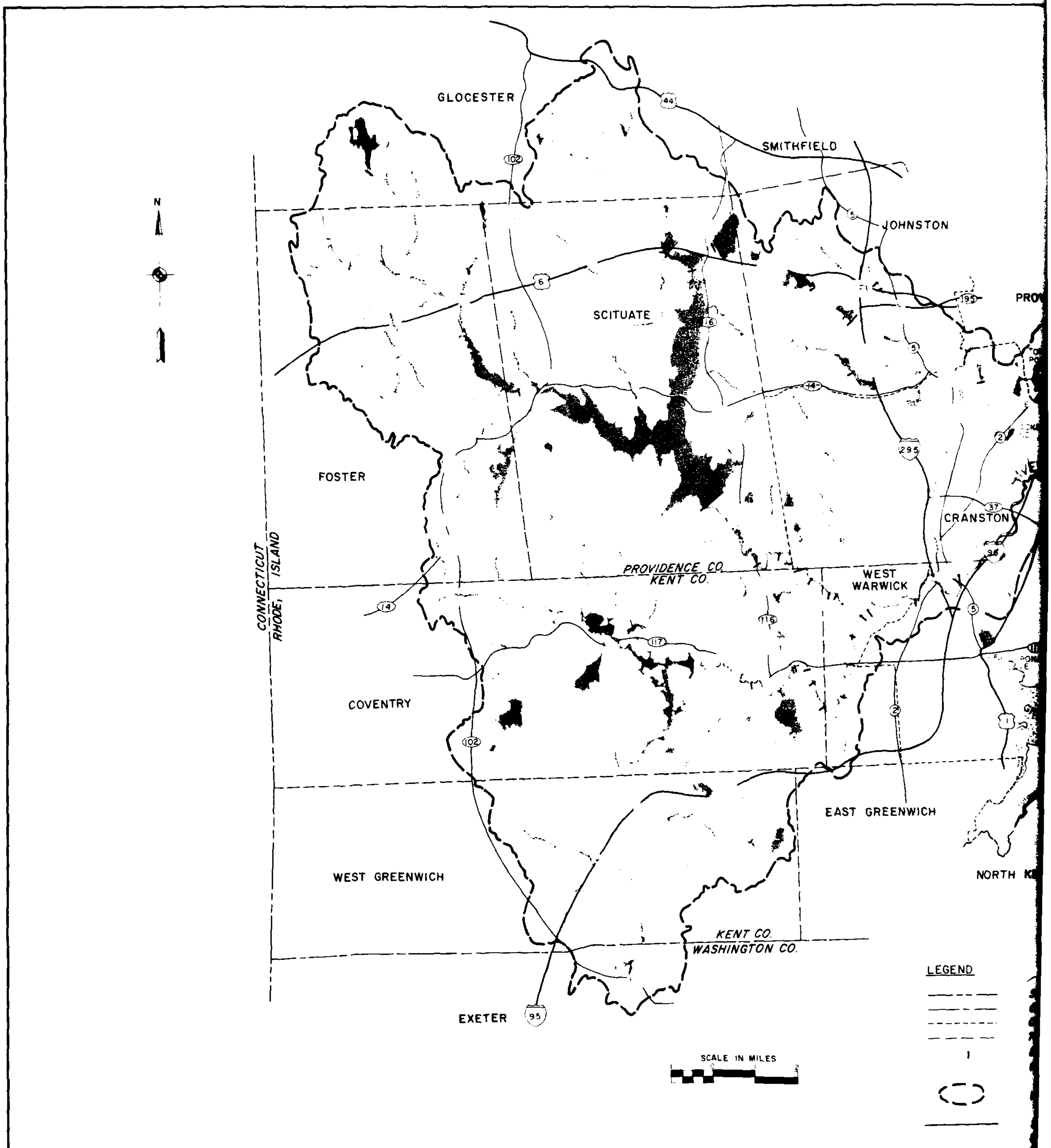
1.06 Regulatory measures would include items such as local participation in the National Flood Insurance Program and a Future Action Program involving reservoir management. The structural elements in the selected plan would be the Warwick Avenue Local Protection Project and the Big River Reservoir.

1.07 The Warwick Ave Local Protection Project. The project would provide relief against riverine and tidal flooding to the low-lying Warwick Avenue area along the south bank of the lower Pawtuxet River. This plan is shown in Figure I-3. It would consist of 3400 feet of dikes, 2400 feet of concrete walls, channel realignment and appurtenant structures which would completely protect more than 450 homes, businesses, and industrial establishments.

1.08 The Big River Reservoir. This component of the structural plan, located in the towns of Coventry and West Greenwich, would provide for flood control storage equivalent to six inches of runoff over a drainage area of about 30 square miles. As presently planned it would be accomplished by increasing the height of the State proposed water supply dam by approximately 3.0 feet. It is shown in Figure I-4. This report will only address the additional 3.0 feet for flood control and not the entire construction and associated impacts relating to the water supply portion of the reservoir. Big River Reservoir will benefit not only the residents of Pawtuxet Basin but the entire State. With water supply becoming a major concern in Rhode Island, Big River will provide the needed supplement in addition to contributing to the solution of the flooding problems on the Pawtuxet River. A separate feasibility study for the reservoir, including an EIS, is part of this report.

1.09 However, due to the lack of local assurances or public support for the Warwick Avenue Local Protection Project, this element of the selected plan is not recommended for construction. Thus, the recommended plan consists of the addition of flood control storage at the proposed Big River Reservoir (if found economically and environmentally acceptable) and the Norwood Land Bank. The Norwood Land Bank would consist of the outright purchase of 40 homes under this option. However, if Big River Reservoir is found not to be feasible, it is recommended that the acquisition plan be expanded to 50 homes, all having a first floor elevation below the 100-year flood.

1.10 Project Economics. The total first cost is estimated at $12,825,000 Federal and $4,275,000 non-Federal. The estimated average annual cost is $1,315,000. The total average annual benefits are described in detail in Appendix 7 of the Technical Appendices to the Main Report. These figures are based on December 1978 price levels. An interest rate of 6-7/8 percent and a project life of 100 years were used in these estimates. With average annual benefits and costs of $2,058,000 and $1,315,000 respectively, the benefit to cost ratio of the selected plan is 1.56 to 1.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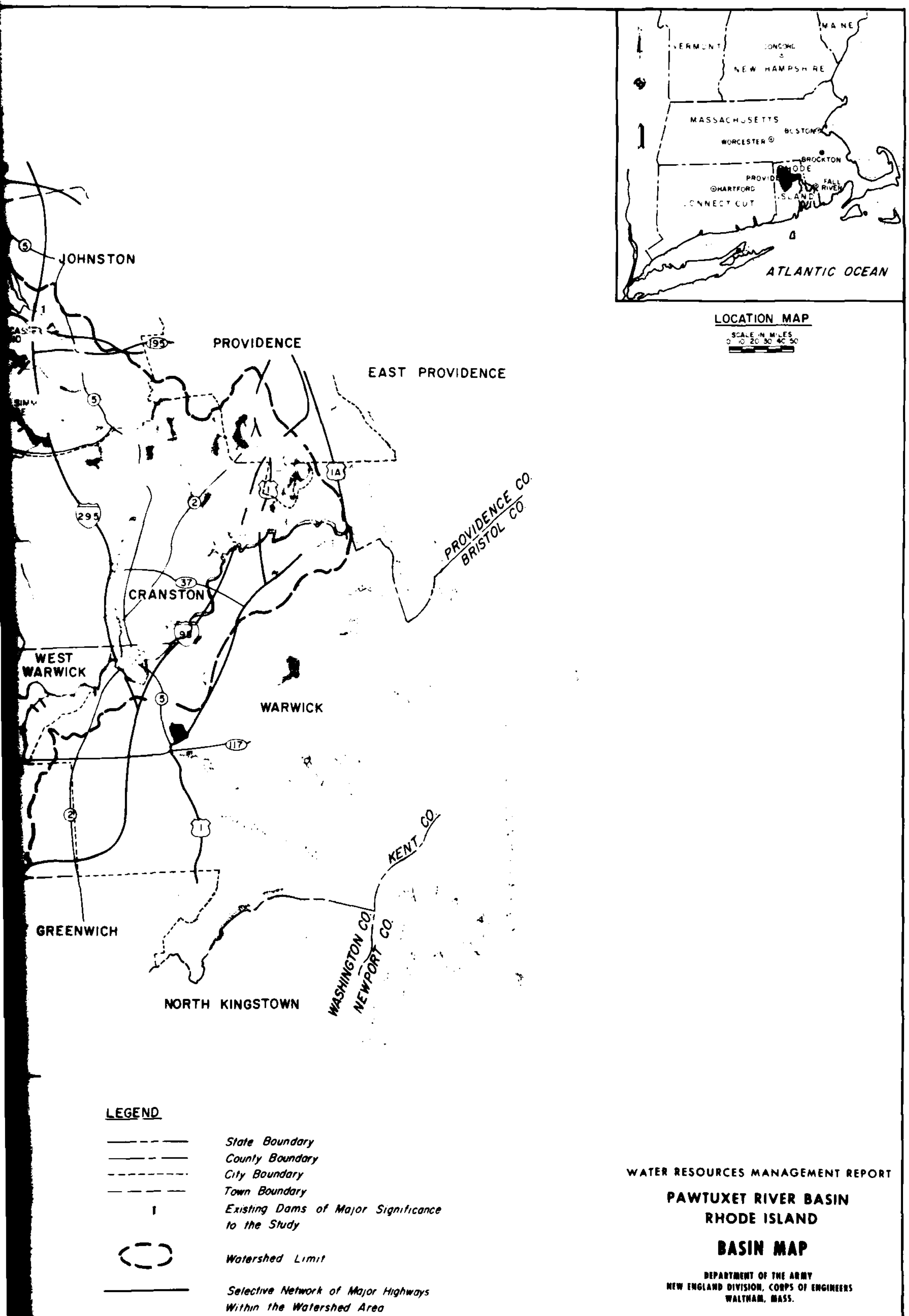
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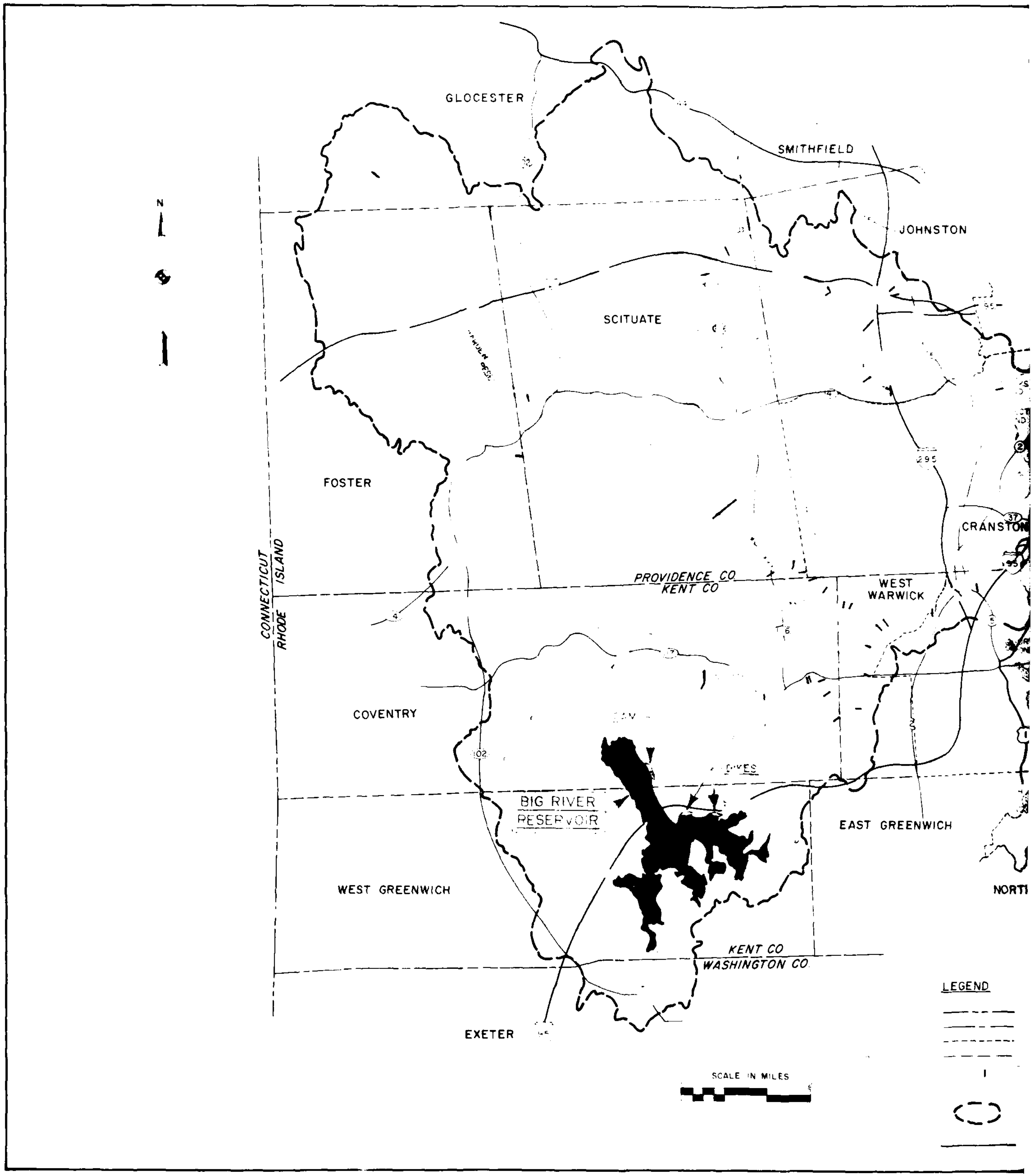
NEWPORT CO.
GREENWICH
NORTH KINGSTOWN
VERMONT
NEW HAMPSHIRE
MAINE
MASSACHUSETTS
WORCESTER
BOSTON
BROCKTON
HARTFORD
CONNECTICUT
RHODE
ISLAND
FALL RIVER
ATLANTIC OCEAN
LOCATION MAP
SCALE IN MILES
0 10 20 30 40 50
LEGEND
State Boundary
County Boundary
City Boundary
Town Boundary
Existing Dams of Major Significance to the Study
Watershed Limit
Selective Network of Major Highways Within the Watershed Area
WATER RESOURCES MANAGEMENT REPORT
PAWTUXET RIVER BASIN
RHODE ISLAND
BASIN MAP
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

FIGURE I-1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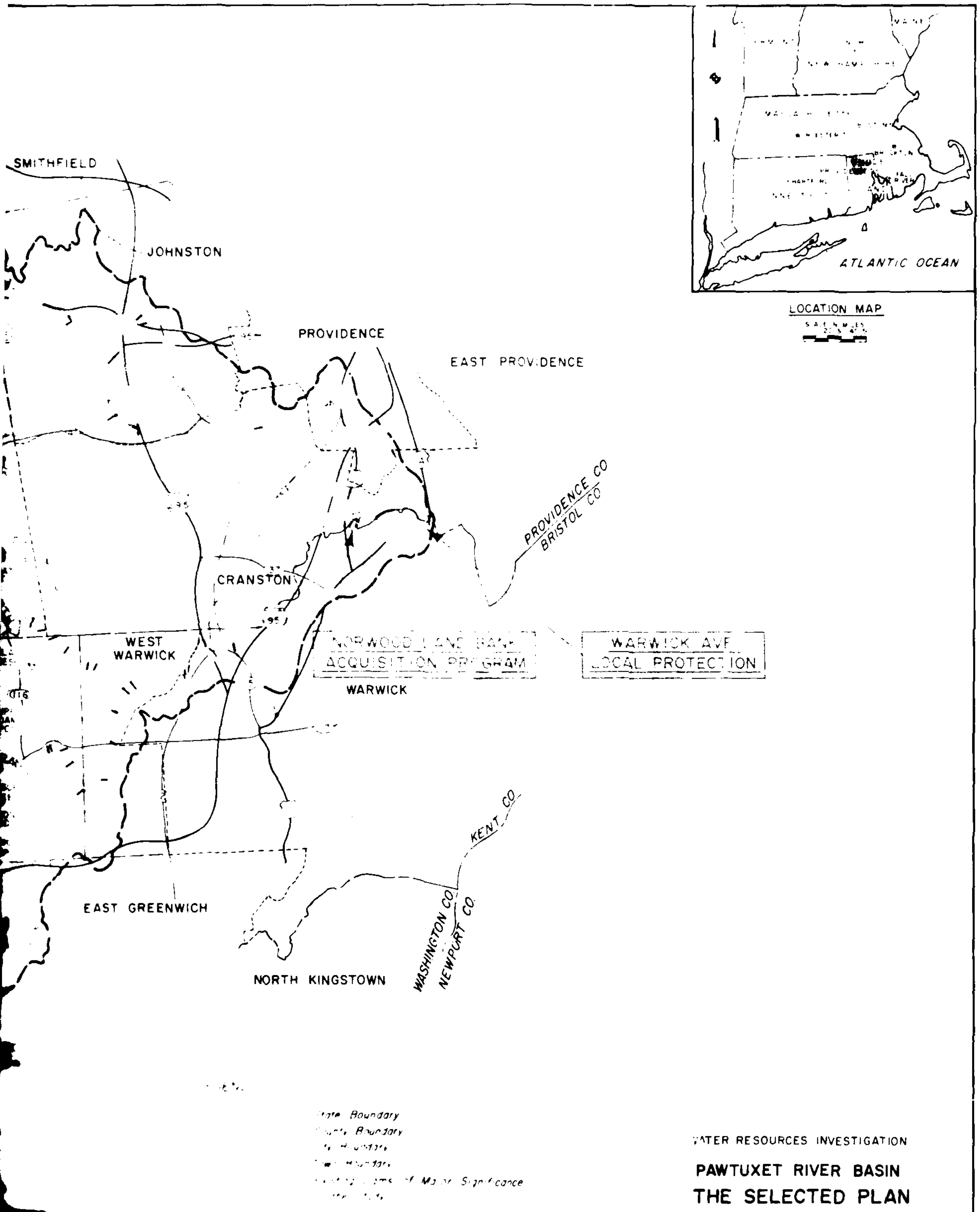
PROVIDENCE CO
KENT CO
WEST WARWICK
COVENTRY
DIKES
BIG RIVER RESERVOIR
EAST GREENWICH
WEST GREENWICH
KENT CO
WASHINGTON CO
EXETER
LEGEND
SCALE IN MILES
N
295
37
102



WATER RESOURCES INVESTIGATION

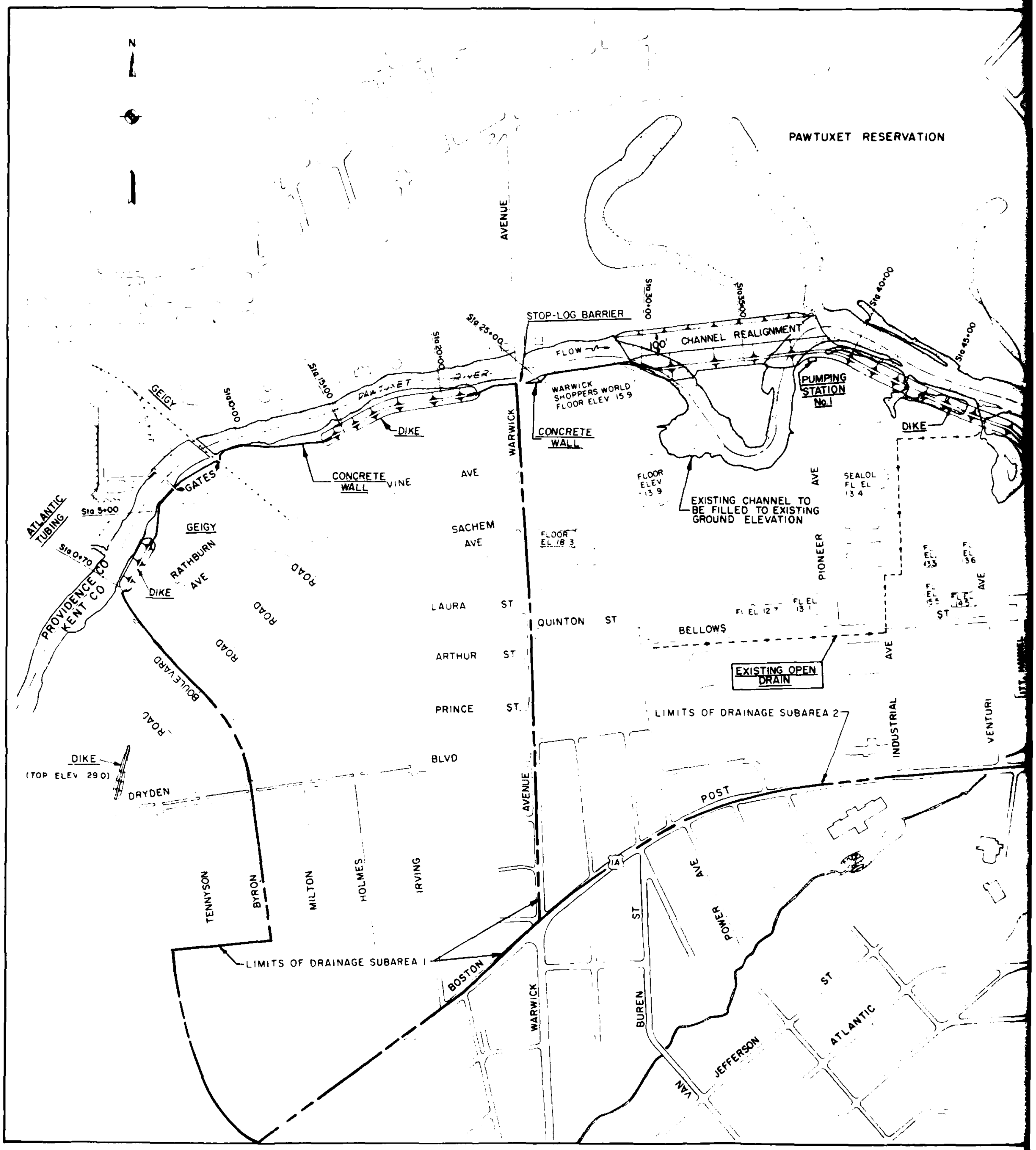
PAWTUXET RIVER BASIN

THE SELECTED PLAN

PAWTUXET RIVER   RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

FIGURE 1-2



N
PAWTUXET RESERVATION
AVENUE
STOP-LOG BARRIER
Sta 25+00
Sta 30+00
Sta 35+00
Sta 40+00
Sta 45+00
Sta 20+00
Sta 15+00
Sta 10+00
Sta 5+00
Sta 0+70
100' CHANNEL REALIGNMENT
FLOW
PAWTUXET RIVER
WARWICK SHOPPERS WORLD FLOOR ELEV 15.9
CONCRETE WALL
PUMPING STATION No.1
DIKE
GEIGY
GATES
ATLANTIC TUBING
PROVIDENCE CO
KENT CO
VINE AVE
FLOOR ELEV 13.9
EXISTING CHANNEL TO BE FILLED TO EXISTING GROUND ELEVATION
SEALOL FL EL 13.4
SACHEM AVE
FLOOR EL 18.3
RATHBURN AVE
ROAD
LAURA ST
QUINTON ST
BELLOWS
PIONEER AVE
ARTHUR ST
PRINCE ST.
BLVD
BOULEVARD
EXISTING OPEN DRAIN
LIMITS OF DRAINAGE SUBAREA 2
INDUSTRIAL
VENTURI
DIKE (TOP ELEV 29.0)
DRYDEN
POST
1A
AVENUE
WARWICK
TENNYSON
BYRON
MILTON
HOLMES
IRVING
LIMITS OF DRAINAGE SUBAREA 1
BOSTON
ST
POWER AVE
BUREN
VAN
JEFFERSON
ATLANTIC

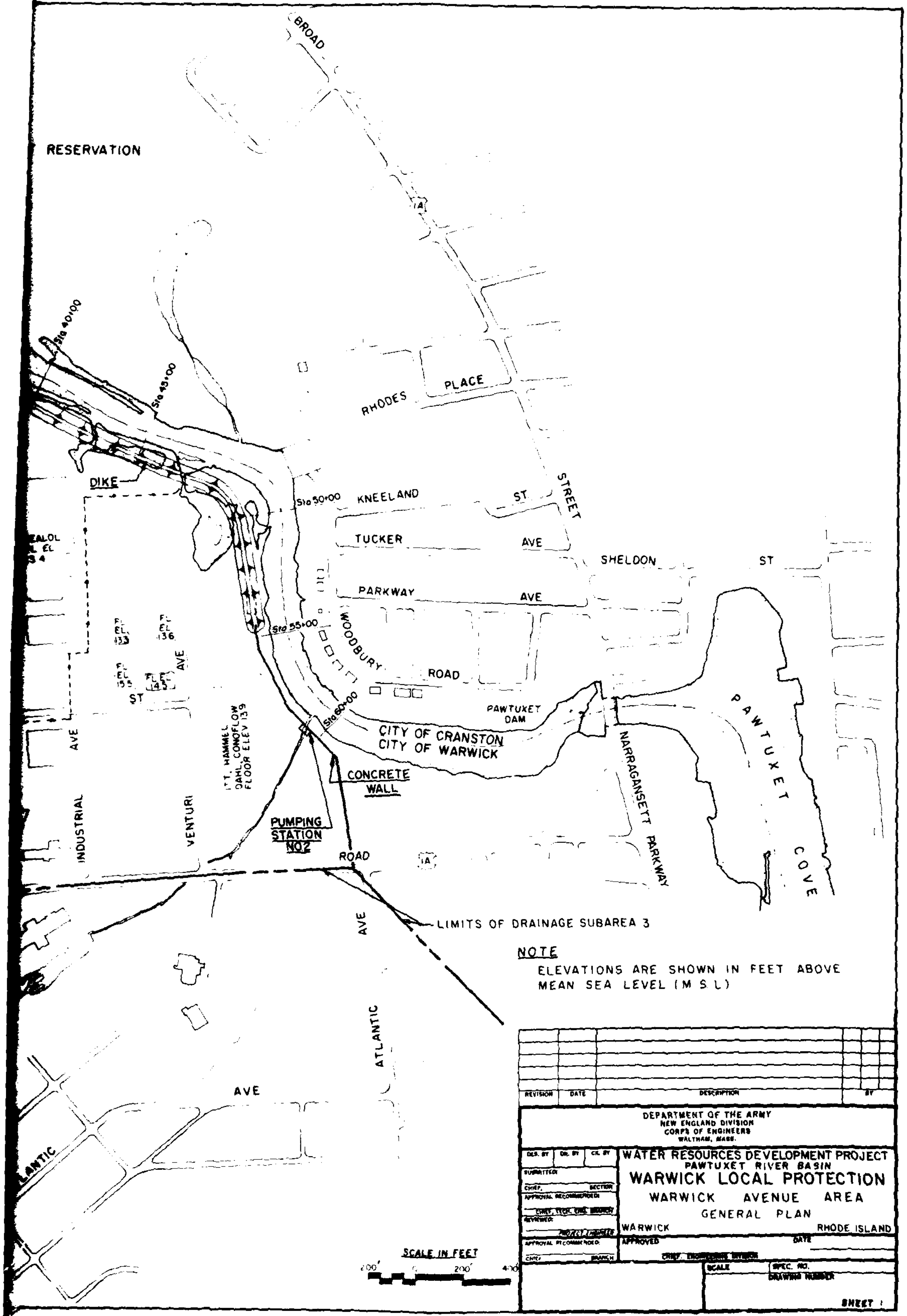
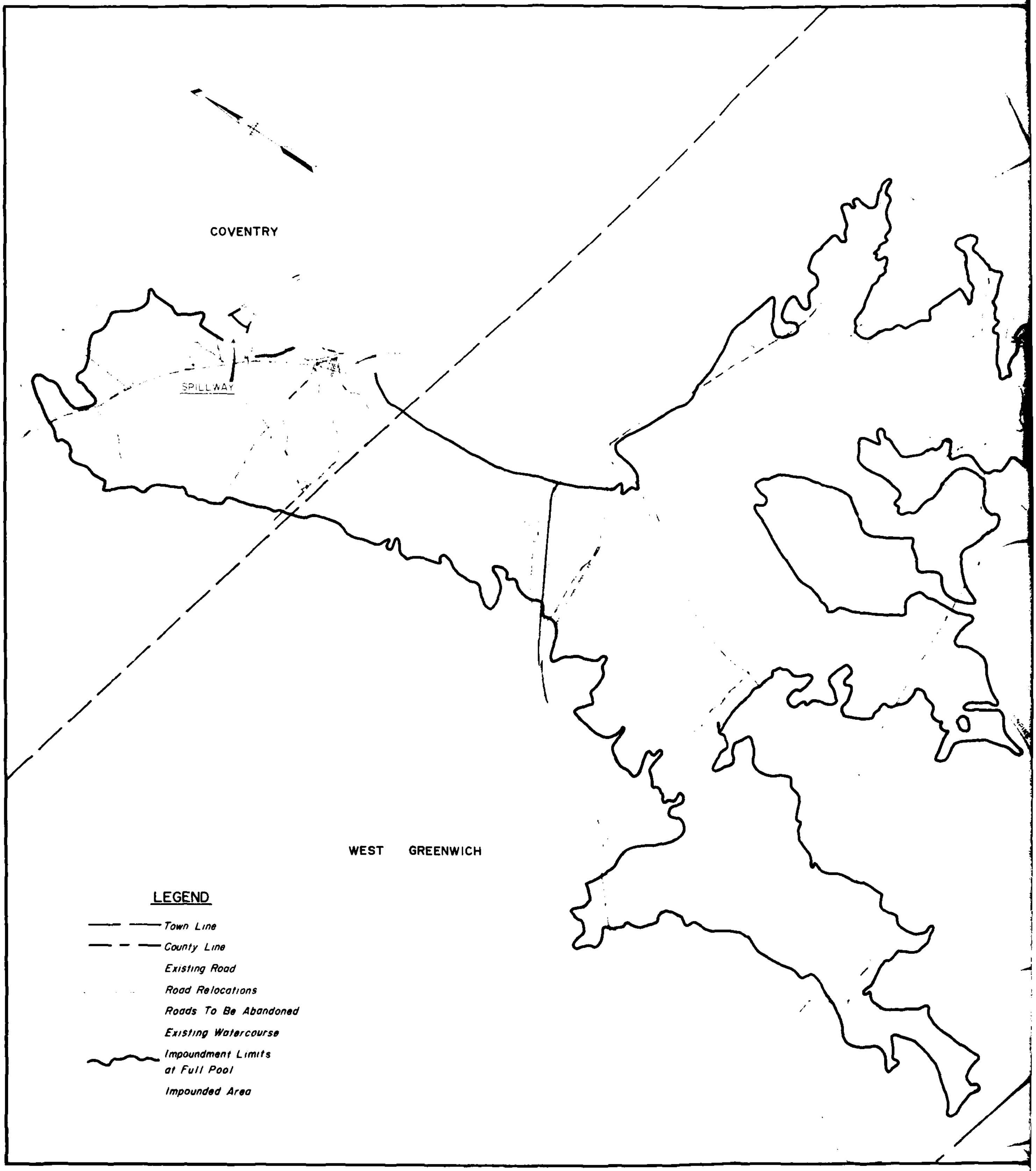

BROAD
RESERVATION
Sta 40+00
Sta 45+00
RHODES PLACE
DIKE
Sta 50+00
KNEELAND ST
STREET
TUCKER AVE
SHELDON ST
PARKWAY AVE
Sta 55+00
WOODBURY ROAD
Sta 60+00
PAWTUXET DAM
CITY OF CRANSTON
CITY OF WARWICK
CONCRETE WALL
NARRAGANSETT PARKWAY
PAWTUXET COVE
PUMPING STATION NO2
ROAD
INDUSTRIAL AVE
VENTURI AVE
LIMITS OF DRAINAGE SUBAREA 3
NOTE
ELEVATIONS ARE SHOWN IN FEET ABOVE MEAN SEA LEVEL (M S L)
ATLANTIC AVE
SCALE IN FEET
200' 0 200' 400'
REVISION DATE DESCRIPTION BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
GENERAL PLAN
WARWICK RHODE ISLAND
APPROVED DATE
SCALE
SPEC. NO.
DRAWING NUMBER
SHEET 1

FIGURE 1-3


COVENTRY
SPILLWAY
WEST GREENWICH
LEGEND
Town Line
County Line
Existing Road
Road Relocations
Roads To Be Abandoned
Existing Watercourse
Impoundment Limits at Full Pool
Impounded Area

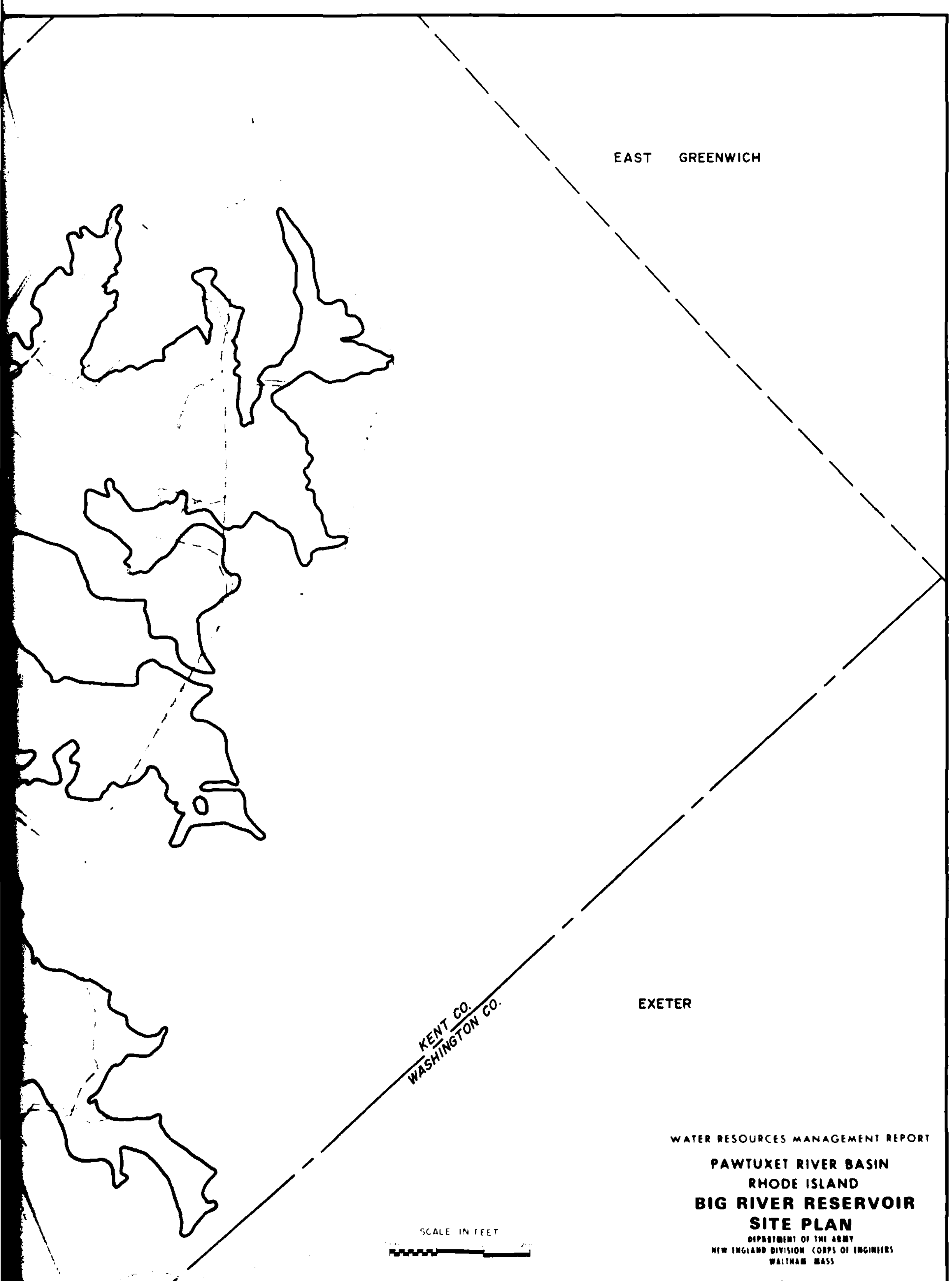

EAST GREENWICH
EXETER
KENT CO.
WASHINGTON CO.
SCALE IN FEET
WATER RESOURCES MANAGEMENT REPORT
PAWTUXET RIVER BASIN
RHODE ISLAND
BIG RIVER RESERVOIR
SITE PLAN
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION CORPS OF ENGINEERS
WALTHAM MASS

FIGURE I-4

2.00 ENVIRONMENTAL SETTING WITHOUT THE PROJECT

2.01 General. Baseline conditions have been organized into three sections - physical setting, natural setting, and human setting. The physical setting covers the physical geography of the Pawtuxet River and its drainage basin. The natural setting describes plant and animal life in the area, and the human setting portion includes the area's social and economic conditions. Existing environmental conditions are described at either a regional level or a local site-specific level, depending on which is more appropriate.

2.02 The Physical Setting. Drainage Basin Description. The 230-square mile Pawtuxet River Basin is located in central Rhode Island (Figure I-1). The river originates in the hilly uplands between Rhode Island and Connecticut and flows easterly to its mouth at Pawtuxet Cove in Narragansett Bay. The watershed contains numerous swamps, a few natural lakes and many ponds and reservoirs. Elevations in the watershed range from 10 feet above sea level in the lower reaches to as high as 800 feet at the western divide.

2.03 The main stem of the Pawtuxet River begins at the junction of the North and South Branches at Riverpoint in the town of West Warwick. From there the river flows generally northeast for approximately 11 miles to Pawtuxet Cove. The North Branch of the Pawtuxet River originates at Scituate Reservoir, a major source of water for Providence. Gainer Memorial Dam (formerly Kent Dam) impounds the Moswansicut and Ponaganset Rivers to form this reservoir. The South Branch of the Pawtuxet River originates at Flat River Reservoir. From there the river flows generally northeast for 9.0 miles until it joins the North Branch at riverpoint.

2.04 The Scituate Reservoir is the largest in the Pawtuxet Basin. This reservoir and five smaller upstream reservoirs are an integral part of the water supply system for Providence and the surrounding area.

2.05 The second largest impoundment in the basin is the Flat River Reservoir, located on the South Branch. It was built and is operated by the Quidnick Reservoir Company along with two small reservoirs, Quidnick and Tioque. These reservoirs are used to maintain flow in the South Branch. There are numerous other small reservoirs and dams in the basin, most of which were originally used by textile mills.

2.06 Although these reservoirs are not operated specifically for flood control, they can have a significant beneficial effect if the dams are only partially full when flooding occurs. For example, Scituate Reservoir helped to reduce the March 1968 flood.

2.07 Weather and Climate. The Pawtuxet River Basin has variable weather conditions that include frequent but generally short periods of heavy precipitation. The basin lies in the path of the prevailing westerly winds which bring cyclonic storms from the west or southwest toward the east or northeast, respectively. The area is also exposed to occasional coastal and tropical storms that travel up the Atlantic seaboard.

2.08 Temperature. The average annual temperature in the Pawtuxet River Basin is about $50^{o}F$ with extremes ranging from highs of $100^{o}F$ to lows of $-15^{o}F$. Freezing temperatures may be expected from the latter part of October until the middle of April.

2.09 Precipitation. The mean annual precipitation over the Pawtuxet River Basin is about 45 inches and occurs almost uniformly throughout the year. However, extremes in monthly rainfall have occurred from a high of more than 12 inches to less than 0.[illegible] inches. The average annual snowfall over the basin is about 40 inches, occurring from December through March. Due to the moderating effect of Narragansett Bay, snow cover usually melts quickly.

2.10 Tides. High tides associated with coastal storms can produce flooding in the lower elevations of the Pawtuxet River Basin. The most serious tidal flooding is generally associated with hurricanes. Recent records show one tide of 15.7 feet in September 1938 and another of 14.7 feet in August 1954. It is estimated that under some conditions the tide level in Narragansett Bay could cause increases in river stage 4.4 miles above the mouth of the river.

2.11 Project Impact Areas. The basins's coastal lowland is covered mostly by an outwash plain of sorted sand and local deposits of coarse gravel. The Pawtuxet River downstream of Natick is bordered by a flood plain deposit of alluvium consisting of fine to medium sand, in places interbedded with gravel.

2.12 The Warwick Avenue Local Protection project would be located on the flood plain deposits of the Pawtuxet River. The selected site for the protective works have not previously been used as a source of commercial sand and gravel.

2.13 Groundwater. Groundwater storage underlying the Pawtuxet River Basin occurs chiefly in bedrock or unconsolidated glacial drift which overlies bedrock. The bedrock consists of a variety of metamorphic and igneous rocks. Water in these rocks is present in fractures and joints. Wells drilled into bedrock are generally reliable for small quantities of water, but only a few wells yield large quantities of water.

2.14 Water Quality. The Pawtuxet River is one of the most polluted in Rhode Island. Water quality in the basin ranges from Class A (suitable for domestic water supply) at Scituate Reservoir and the Big River, Class B (suitable for domestic water supply with appropriate treatment and for swimming) at Flat River Reservoir and the upper reaches of the North and South Branches, Class C (suitable for fish and wildlife habitat and boating) for most of the main stem. While at times conformation to these classifications varies they remain long term goals as established in 1977 by the Rhode Island Department of Health. A map showing these water quality classifications is presented in Figure II-1. Although the environmental objective of the Federal Water Pollution Control Act amendments of 1972 is to attain a minimum of Class B waters everywhere, economic and technologic limitations could preclude such attainment in the lower Pawtuxet River Basin.

2.15 Water quality degradation within the basin can be attributed to both rural and urban problems. The rural problems along the upper reaches of the North and South Branches can be attributed to the lack of municipal treatment facilities. Inadequate subsurface disposal units, incomplete onsite treatment of industrial wastes and frequent occurrence of low flow conditions contribute at times to high pollutional loadings.

2.16 The urban problems, along the lower reaches of the North and South Branches and along the main stem, are caused by urban runoff and the effluents from these three municipal treatment facilities and several industrial and State institutional treatment facilities. Although all facilities provide the equivalent of secondary treatment, significant pollutional loadings remain in the discharges that further degrade the already impaired water quality caused by the upstream conditions. In addition, dams along the South Branch and the main stem cause sluggish flows and sedimentation of settleable solids, including organic wastes, thereby reducing dissolved oxygen levels.

2.17 There are four basic future needs within the basin: 1) provision of the proposed regional treatment facility in Coventry, expansion and or modification of the existing Warwick, West Warwick, and Cranston treatment facilities; 2) addition of more sophisticated treatment components at existing treatment plants to remove any objectionable parameters; 3) expansion of existing treatment facilities as needed to handle future growth, and 4) resolution of the existing problem of insufficient low flows throughout the lower basin. Some of these needs may not be possible to resolve.

2.18 Water quality sampling is conducted on a periodic basis by the Rhode Island Department of Health. Water quality data in association with related projects for the basin has been collected by the Corps of Engineers together with the Federal Environmental

Protection Agency (EPA) for two stations on the main stem and one station each on the North and South Branches. Water sampling began in September 1975 and continued on a monthly basis to April 1976. The results are presented in Table II-1. On the main stem, Station 1 is located at the Broad Street Bridge near the mouth of the Pawtuxet River, and Station 2 at the Providence Street Bridge (Route 33) in West Warwick - Warwick just upstream of the Natick Dam. Station 3 is located along the South Branch at the Providence Street Bridge in West Warwick, just upstream from the confluence with the North Branch. Station 4 is located along the North Branch at the Main Street Bridge in West Warwick.

2.19 Existing Wastewater Treatment Facilities. Three major secondary sanitary systems in the Pawtuxet Basin collect and treat wastewater. They are the Cranston, Warwick and West Warwick systems, serving those communities, respectively.

2.20 The Cranston plant is located on the Pawtuxet River at about river mile 4.5. It is virtually floodproof for all conditions except for events greater than the 100-year event, though some modifications of the pumps may be necessary to operate properly under high water conditions. Sludge produced in the plant is currently stored on land near the edge of the river, where it would be inundated by flood flows. A 100-year flood is one having a one-percent chance of occurrence in any given year. It is based on statistical analysis of streamflow records available for the watershed and analyses of rainfall and runoff characteristics in the watershed and nearby region.

2.21 The Warwick wastewater treatment plant is located on the Pawtuxet River at river mile 5.5. Major portions of the treatment facilities would be subject to flooding during the 100-year event.

2.22 The West Warwick sewage treatment plant is located on the Pawtuxet River at river mile 9.1. Its secondary treatment facilities would be flooded by the 25-year flood under future hydrologic conditions. Sludge from the plant is currently stored on land near the edge of the river and can be affected by river flows. Several other treatment facilities are currently provided by industrial firms in the basin such as the American Hoescht Corporation, Falvey Linen Supply and Ciba Geigy.

2.23 Expected Flooding Without the Project. Without flood protection considerable damage would occur along the lower Pawtuxet River, particularly in commercial and industrial areas. The March 1968 flood, which is considered to be less than a 15-year event, caused considerable damage. Since then, new development has taken place and a similar flow would cause even greater damage now.

TABLE II-1

WATER QUALITY SAMPLING S
(September 1975-March 197

	STATION 1		STATION 2	
	Minimum	Maximum	Minimum	Maximum
Average Daily Flow (cfs)*	137	679	-	-
Water Temperature (°C)	3.0	18.5	3.0	18.5
pH (units) (neutrality = 7.0)	5.7	7.6	5.3	7.7
Total Coliform (bacteria/100 ml)	1,700	92,000	2,400	240,000
Fecal Coliform (bacteria/100 ml)	170	54,000	490	34,000
Ammonia-Nitrogen Demand (mg/l)	0.10	2.00	0.05	0.80
Dissolved Oxygen (D.O.) (mg/l)	7.0	14.0	7.0	14.0
Biochemical Oxygen Demand - 5 Day (B.O.D.$_5$) (mg/l)	2.0	12.8	1.8	29.8
Chemical Oxygen Demand (C.O.D.) (mg/l)	16	37	9	58
Total Nonfilterable Residue (mg/l)	1	9	2	27
Volatile Nonfilterable Residue (mg/l)	1	6	1	4

* At U.S.G.S. Gage in Cranston

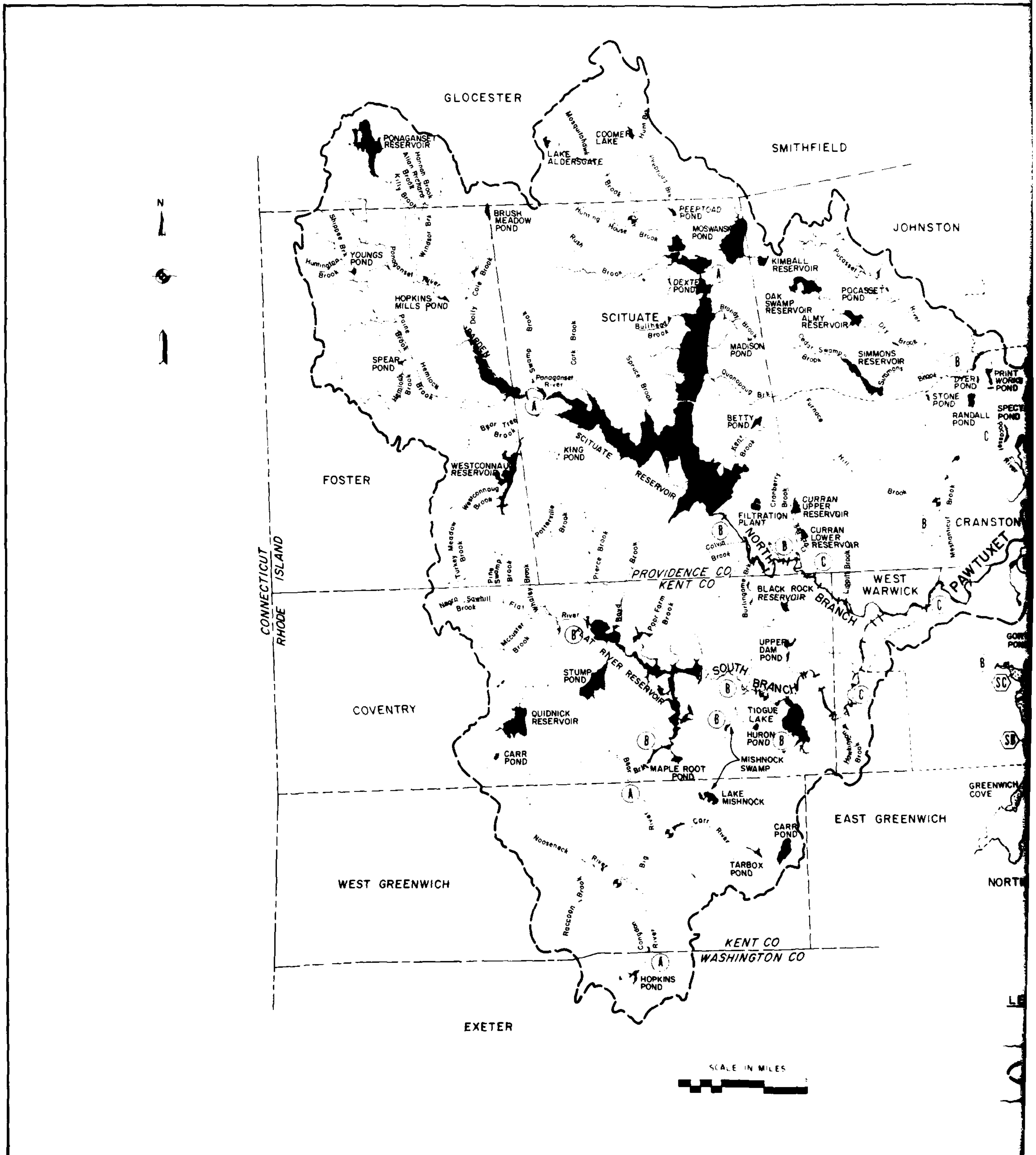
Station Locations:
Station 1 - Pawtuxet River at Broad Street, Cranston.
Station 2 - Pawtuxet River at Providence Street, West Warwick
Station 3 - South Branch Pawtuxet River at Route 33, West Warwick.
Station 4 - North Branch Pawtuxet River at Route 115, West Warwick.

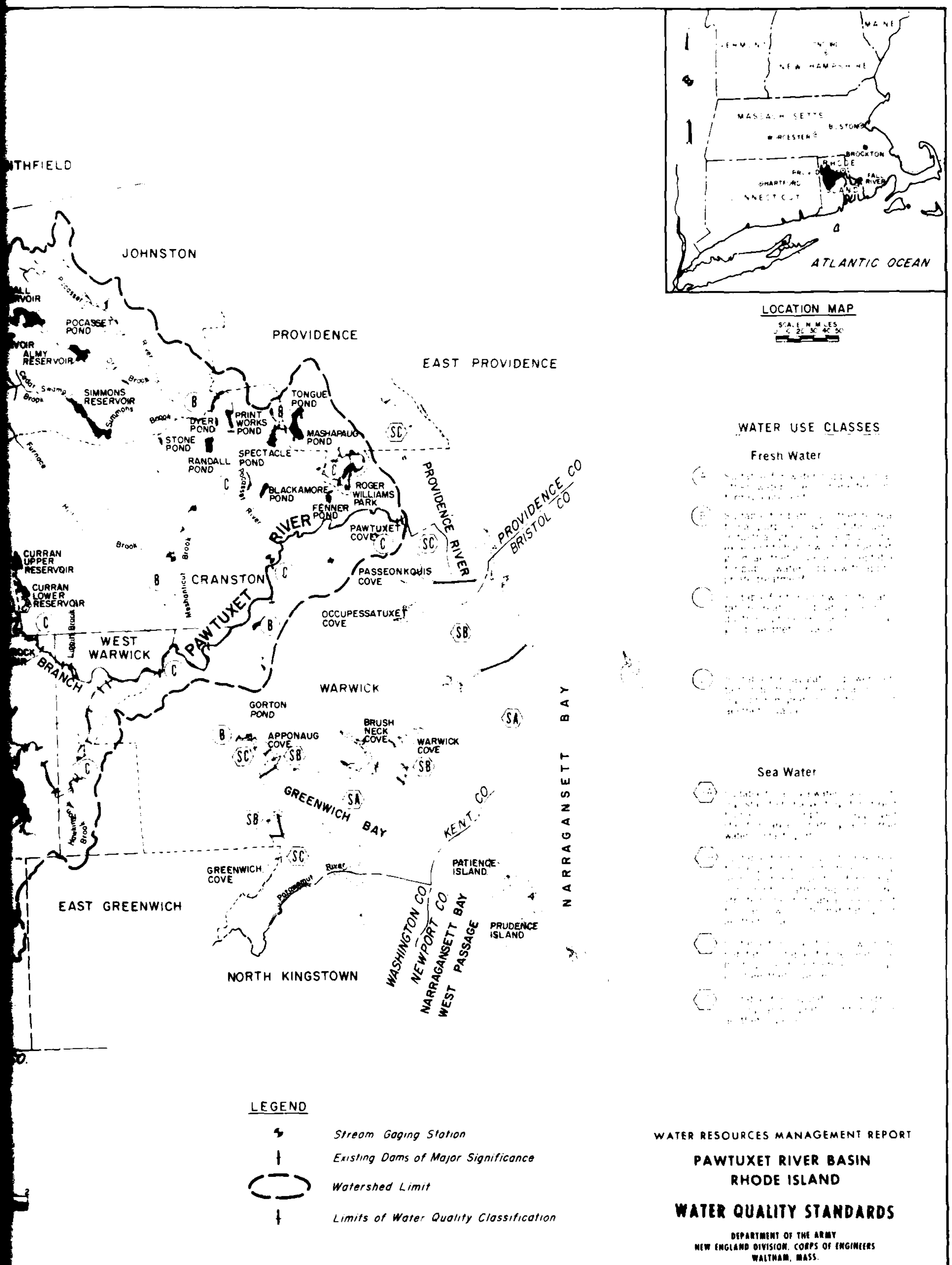
E II-1

AMPLING STATIONS
5-March 1976)

N 2	STATION 3		STATION 4	
Maximum	Minimum	Maximum	Minimum	Maximum
-	-	-	-	-
18.5	3.0	19.0	3.0	18.0
7.7	5.2	7.5	6.0	7.6
240,000	9,200	350,000	400	160,000
34,000	620	160,000	140	13,000
0.80	0.05	0.70	0.05	0.90
14.0	6.6	16.0	8.1	14.0
29.8	3.9	16.2	1.6	5.1
58	27	46	5	34
27	2	10	1	10
4	1	6	1	6

wick.
rwick.


GLOCESTER
SMITHFIELD
JOHNSTON
FOSTER
SCITUATE
CRANSTON
COVENTRY
WEST WARWICK
EAST GREENWICH
WEST GREENWICH
EXETER
CONNECTICUT
RHODE ISLAND
PROVIDENCE CO
KENT CO
WASHINGTON CO
PONAGANSET RESERVOIR
COOMER LAKE
LAKE ALDERSGATE
PEEPTOAD POND
MOSWANSICUT POND
BRUSH MEADOW POND
YOUNGS POND
HOPKINS MILLS POND
SPEAR POND
KIMBALL RESERVOIR
OAK SWAMP RESERVOIR
ALMY RESERVOIR
POCASSET POND
MADISON POND
SIMMONS RESERVOIR
BETTY POND
KING POND
SCITUATE RESERVOIR
WESTCONNAUG RESERVOIR
DYER POND
STONE POND
RANDALL POND
PRINT WORKS POND
FILTRATION PLANT
CURRAN UPPER RESERVOIR
CURRAN LOWER RESERVOIR
NORTH BRANCH
PAWTUXET
BLACK ROCK RESERVOIR
UPPER DAM POND
SOUTH BRANCH
FLAT RIVER RESERVOIR
STUMP POND
QUIDNICK RESERVOIR
TIOGUE LAKE
HURON POND
CARR POND
MAPLE ROOT POND
MISHNOCK SWAMP
LAKE MISHNOCK
TARBOX POND
GREENWICH COVE
HOPKINS POND
SCALE IN MILES



WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

WATER QUALITY STANDARDS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

FIGURE II-1

2.24 In future years increasing development in the watershed can be expected to increase flooding in two ways. Additional pavements and rooftops will cause more water to run into the river instead of into the ground. Also, the destruction of the natural areas and wetlands that act as storage areas for precipitation, will increase the speed of the runoff.

2.25 In the Warwick Industrial Park and the Geigy area riverine flooding of a 100-year frequency would create flood stages ranging from 14.0 feet near ITT Hammel Dahl and 15.8 feet on the downstream side of Warwick Avenue to 19.8 feet upstream of the pedestrian bridge at Ciba Geigy. These elevations are based upon 1970 hydrologic conditions and are relative to mean sea level (msl). This flooding would produce water depths of one to four feet above most first floor elevations throughout the entire industrial park area. Greater depths of four to six feet above first floor elevations would affect areas near the Ciba Geigy Chemical Works. For the same reference points under future conditions, we would have elevations of 15.0, 16.7 and 21.0 feet, respectively.

2.26 Flood stages for a standard project flood would range from 21.5 to 22.6 to 26.6 at the above points, respectively, under 1970 hydrologic conditions. This would cause flood stages approximately seven feet above those for the 100-year event. Under future conditions at the same points, flood stages of approximately 23.3, 24.6 and 27.8 feet, respectively, would result. This corresponds to depths of water above the first floor slabs ranging from maximums of 10 feet in Sealol to 14 feet in some of Geigy's buildings.

2.27 <u>The Natural Setting</u>. <u>General</u>. The section covers the natural ecology of the project area and discusses plant and animal life likely to be affected by the proposed project.

2.28 <u>Warwick Avenue Area</u>. Along the river in the Warwick Avenue industrial area, topography, soils and drainage patterns have combined to produce a complex of sites that are occupied by small basins of freshwater marsh, wooded swamps and the plants associated with a flood plain community.

2.29 The freshwater marshes contain dense stands of tussock grass and cattail in standing water. The domination of these two plants and the lack of open water reduces the diversity of the plant community. However, the marshes are being invaded by red maple seedlings, and ultimately these marshes will become wooded swamps through the natural process of plant succession.

2.30 <u>Vegetation Communities</u>. The vegetation in the Warwick Industrial Park area is limited, consisting of swamp forest in the riverside locations with successional types scattered throughout.

AD-A105 823 CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV F/G 13/2
BIG RIVER RESERVOIR PROJECT - PAWCATUCK RIVER AND NARRAGANSETT --ETC(U)
JUL 81

UNCLASSIFIED NL

3 OF 9

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105823

Some of the successional plants have appeared after flooding or natural channel cutting, while others took hold because of man's use of the land. Those species present are silver maple, slippery elm, red maple, red ash, aspen and swamp white oak with high bush blueberry, sweet pepper bush, arrowwood, green briar, sheep laurel, dogwood, alder and willow forming a dense understory. Various grasses and sedges along with ferns and mosses form the ground cover. Groups of skunk cabbage and cowslips are also present.

2.31 Common mammals using the wetlands along the river are the starnosed mole, muskrat, racoon, opossum, little brown bat, cottontail rabbit, chipmunk, gray squirrel, flying squirrel, Norway rat and skunk. Mink, otter and red fox may also pass through the area.

2.32 Many species of ducks, including the wood duck, black duck, mallard and teal, use the sedge-cattail areas as well as the river flood plains. Killdeer and snipe are visitors to the marshes. Flickers and downy and hairy woodpeckers are common throughout the swamp woodlands along with blue jays, crows, chickadees, nuthatches and other creepers. Many species nest throughout the wetlands while others are visitors on a seasonal basis.

2.33 On the Cranston side of the river, opposite the Industrial Park, is a sizeable forested flood plain called the Pawtuxet Reservation. A State-owned property, it is the largest green space in either Warwick and Cranston. The plant species present here are similar to those on the Warwick side, but they are more extensive and probably contain a wider variety of plant materials.

2.34 Big River Reservoir Area. The vegetation communities of the study area are diverse, and include pure stands of hardwoods and conifers. Wetland vegetation types appear widely distributed throughout the area and consist mainly of swamp forest, fresh marsh, and shrub swamp. There are no extensive agricultural lands present in the study area.

2.35 The dominance of coniferous vegetation is the most striking natural feature of the study area. Fully 75 percent of the area contains conifers, either in pure or mixed association. The predominant species are white pine and pitch pine. Lowland forests are dominated by red maple, swamp white oak, elm and red ash. The swamps contain dense stands of highbush blueberry, spice bush, sweet pepper bush, swamp azalea and witch hazel.

2.36 Dense aggregations of herbaceous plants are present in the lowland forests and include skunk cabbage, sphagnum moss, interrupted fern, wood ferns of various types and royal fern.

2.37 The study area contains varied wildlife habitats including forest, successional lands, farm fields, wetlands, ponds and streams.

2.38 Common mammals include white-tailed deer, red and gray fox, various shrews and bats, along with cottontail rabbits, snowshoe hare and such rodents as the chipmunk, woodchuck, and red, gray and flying squirrels. The mouse and mole populations form a food basis for predators.

2.39 A number of valuable fur-bearing mammals are also common to the study area. They include racoon, long-tailed weasel, muskrat, mink, otter and possibly the bobcat.

2.40 The variety of habitats in the study area is also attractive to various bird species, and the extensive conifer vegetation provides food and shelter for numerous song birds that occupy all strata of the forest. Some species, such as the crossbill, feed extensively on seeds of conifers and may use these areas as wintering grounds.

2.41 Birds of the area include the red-tailed hawk, marsh hawk, sparrow hawk, ruffed grouse, bob-white quail, ring-necked pheasant, morning dove, cuckoos, great-horned owl, goat suckers, swifts, hummingbirds, various flycatchers, woodpeckers and swallows. The blue jay, crow, chickadees, nuthatches, creepers and thrushes are common. During the spring and fall migrations, large numbers of woodland warblers are present including the black and white, bluewinged, Tennessee, parula, yellow, magnolea and Cape May as well as the myrtle chestnut-sided ovenbird. Large numbers of black birds, sparrows and various finches use the area and breeding population of the scarlet tanager and cardinal are also present.

2.42 The streams, ponds, swamps and marshes of the area contain a wide variety of aquatic birds and mammals. Waterfowl species such as the mallard, black duck, wood duck and blue-winged teal breed in the area, and during the migratory season they are joined by Canada geese, green winged teal, pidgeon, shovelers and ring-necked ducks. Wading birds such as the great-blue heron, bittern, egret and black crowned night heron are present along with various shore birds, rails and coots.

2.43 The Human Setting.

2.44 General. The description of the human setting addresses population trends, land use and economic development in the study area. It also includes social and cultural characteristics as well as recreation, historic/archaeologic and aesthetic considerations. Transportation facilities and the related noise and air quality are also addressed.

2.45 Population Trends. Within the five municipalities in the project impact area (Cranston, Warwick, West Warwick, Coventry and West Greenwich) population increased during the 1960-1970 period from 172,116 to 205,253. Population trends and projections were compiled by RISWPA, the Corps and by OBERS.* The OBERS population projection for this area (excluding West Greenwich) for 1990 is 260,400, for an average annual growth rate of 1.2 percent. This compares with the Planning Agency estimate of 250,700, at a growth rate of 1.05 percent.

2.46 Long-range projections by OBERS for the year 2020 show an increase in this area to 368,100, indicating an average annual growth rate of 1.2 percent. The Corps of Engineers has forecast a population of 313,875 for that year, an annual growth rate of 0.75 percent.

2.47 Coventry. The population of Coventry grew from 15,432 to 22,947 during the 1960-1970 period, an average annual growth rate of almost four times that of the State of Rhode Island. The RISWPA estimate of the 1990 population for Coventry is 32,100, while the OBERS projection is 41,000. Both estimates show that Coventry's population will continue to grow, primarily because of immigration, but at a decreasing rate.

2.48 Warwick. With a population increase of 15,190 in the 1960's and an annual growth rate of 2.1 percent during that period, Warwick remains the second largest city in Rhode Island. Its growth rate is double the State's as a whole. RISWPA and OBERS projections for the year 1990 estimate Warwick's population at 105,900 and 113,300, respectively. It is assumed that Warwick's population will grow at a decreasing rate and may approach the State's rate over the long term.

2.49 Cranston. Cranston's population grew from 66,766 to 74,287, an annual growth rate of 1.1 percent, between 1960 and 1970. Projections for 1990 show a decrease in the average annual growth rate of 0.15 percent and 0.8 percent for OBERS and the RISWPA, respectively. Projections for the year 2020 show a drop in the growth rate to 0.75 (Corps of Engineers) and a negative rate of -0.3 (OBERS). Cranston's growth rate is expected to decrease below the State's growth rate.

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*OBERS: projections compiled for the Water Resources Council by the Bureau of Economic Analysis of the Dept. of Commerce and the Economic Research Service of the Department of Agriculture.

RISWPA: Rhode Island Statewide Planning Agency

2.50 West Warwick. The town of West Warwick grew at an average annual rate of 0.75 percent between 1950 and 1960 and at a 1.3 percent rate between 1960 and 1970. The town's growth rate is expected to remain constant or decline slightly.

2.51 West Greenwich. The population of West Greenwich grew from 1,169 to 1,841 between 1960 and 1970, for an average annual growth rate of 4.7 percent. The OBERS projections for the population of West Greenwich show 3,600 residents in 1990 and 9,300 in 2020, for annual average growth rates of 3.4 and 3.2, respectively. The statistics indicate that West Greenwich is a steadily developing small town.

2.52 Economic Development In order to effectively analyze the economic impact of the project on the Pawtuxet River area, it is necessary to view the study area in a regional and historic context.

2.53 During the mid-20th century, there was a trend away from manufacturing toward a more diversified economic base stressing general service industries. During 1950-1958, Rhode Island's economy experienced a substantial decline, culminating in the loss of 26,000 jobs in the 1958 recession. From 1958 to 1964, the annual growth rate in service-producing industries almost doubled and the State gained an average of 3,500 jobs/year.* This upsurge, though, was not enough to offset the continuing loss of manufacturing jobs. Despite excellent location and transportation factors, older industries have declined without corresponding gains in service sectors.

2.54 Future Trends. Economic activity in the Providence-Pawtuxet-Warwick subarea is expected to decline despite the shifts in employment and the diversification of Rhode Island's economy.

2.55 Warwick According to the Rhode Island Department of Employment Security (DES), the largest employment categories in Warwick in 1972 were manufacturing, wholesale and retail trade, and service industries.

2.56 Present trends indicate a strong upsurge in wholesaling, retailing and the service sector. Local strip commercial development, shopping malls and discount stores have succeeded in capturing an increasingly larger share of the Warwick trade market. In 1958, Warwick received only 10 percent of its own trade market, as

*Community Renewal Program, Warwick Planning Department, Warwick, RI, p. 4

compared with 42 percent in 1970 and an estimated 63 percent by 1980*. A 1975 "Warwick Profile"** shows that Warwick currently has a diverse industrial/commercial base.

2.57 Projected trends indicate continued increases in the service sector and stabilization in manufacturing, with growth over the next 10 years about equalling the 1960-70 increase.

2.58 In the Warwick Industrial Park which would be protected by the proposed local protection works, there were 1,500 people employed in 1971 at an annual payroll of $[illegible],700,000.***

2.59 Cranston. Cranston's economic trends and development are similar to the city of Warwick's. According to Corps figures,**** Cranston's annual civilian labor force growth rate for 1960-1970 period. The employment in goods-producing industries in Cranston has decreased from 43.5 percent to 3.5 percent, while employment in services producing industries increased from 56.5 percent to 62.5 percent. This trend is expected to continue for a few years and then level off.

2.60 West Warwick and Coventry. Trends indicate that the growth rates of these two towns are decreasing. As in Cranston and Warwick, employment in service industries displaced employment in goods-producing industries between 1960 and 1970. In Coventry, manufacturing employment decreased from 55.7 percent to 48.5 percent, while service employment increased from 44.7 to 51.5 percent. In West Warwick, goods-producing employment decreased 55.7 percent to 47.0 percent, while service employment increased from 44.7 to 53.0 percent. Trends in this direction are expected to continue through the next decade and then level off.

2.61 Shellfishing Industry. Although specific employment data for the shellfishing industry is unavailable, selected statistics indicate its importance to the local economy. The Rhode Island

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*Community Renewal Program, Warwick Planning Department, Warwick, RI, p4

**Community Renewal Program, Warwick Planning Department, Warwick, RI, p. 11

***1971 Corps Report, p. 10

****Unpublished statistics prepared by the New England Division of the Corps of Engineers

Agricultural Experiment Station has estimated that local shellfishing is a million-dollar a year industry. A Corps report states that in 1972 the amount of shellfish handled in Apponaug Cove and Greenwich Bay by ship totalled 16 and 560 tons, respectively.*

2.62 Social and Cultural Characteristics. A recent survey** of the two most potentially affected project impact towns, Warwick and Cranston, indicates the presence of a strong sense of community.

2.63 Warwick residents are fond of their city and most feel deep loyalties to it. Important widely held values include the ability to maintain a suburban lifestyle, home ownerships, a good education system, participation in religious and civic organizations and proximity to the seacoast. Flood control and flood plain zoning were frequently cited as important local issues, although coastal flooding appears to be a greater concern than riverine flooding.

2.64 Residents of Cranston are also proud of their city and they frequently expressed the hope that it "stays the way it is." Important local values are similar to those held by Warwick residents. Flood control and flood plain zoning were not major concerns for most residents interviewed, although several said that flooding was a problem.

2.65 Recreation Resources. Within the primary project area are several public recreation areas and several wetlands and environmental preservation areas. While only a few of these provide facilities for active recreational pursuits, others offer potential for passive recreational pursuits, others offer potential for passive recreational uses and contribute important environmental, ecological, and visual amenities. The lower section of the Pawtuxet River offers important visual amenities, although its polluted state makes it unsuitable for water contact activities.

2.66 Recreational opportunities in the project area are limited to ball fields located within the Pawtuxet Reservation (Fay Memorial Field) and at State Route 2 where it crosses the river (Natick Field). Of the remaining lands offering recreational potential, nearly all are either wetlands generally unsuitable for development or areas specifically designated for environmental preservation. These include the Pawtuxet Reservation, the Pawtuxet

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*Waterborne Commerce of the United States 1972, Part I: Waterways and Harbors for the Atlantic Coast, U.S. Department of the Army, Corps of Engineers

**Unpublished study conducted in 1974 by the Corps of Engineers.

River Reservation (and wetlands immediately upstream), and a State conservation strip (adjacent to Howard Industrial Park), all of which are located on the Cranston side of the Pawtuxet River. Roger Williams Park, the only large park in the area, is beyond the primary project sites and would not be affected by the project.

2.67 Historic and Archaeological Resources. At the time that the Natick Diversion was under consideration, (1976) coordination was performed with the Rhode Island Historic Preservation Commission. No significant resources within the proposed project area were identified at that time.

2.68 Potential impact of flood control capacity within the proposed Big River Reservoir is currently being examined for the Feasibility Report and Environmental Impact Statement associated with that project. No known prehistoric or historic resources are located between the proposed maximum reservoir pool of 302.5 msl and flood pool of 305.0 msl. If more advanced design study at Big River Reservoir is authorized by Congress, further cultural resource studies will be undertaken within the area. Coordination is being maintained with the Rhode Island Historic Preservation Commission.

2.69 Aesthetic Conditions. The Warwick Industrial Park is an assortment of low-profile industrial and commercial buildings with adjoining parking lots. It is located on low-lying, fairly level terrain. For the most part, the visual quality of the area is rather poor. Vacant lots have accumulated debris and are in need of an overall cleanup. A number of businesses have made an effort to upgrade the aesthetics of the area by landscaping their grounds. (The entrance to Sealol Company and the land behind ITT Hammel Dahl are examples of such efforts.)

2.70 Across from the industrial park on the Cranston side of the river, is the Pawtuxet Reservation. It offers a natural setting of forest areas and wetlands, allowing visual enjoyment of the waterfront.

2.71 The area where the Big River Reservoir is proposed is largely undeveloped. Its vegetation, wildlife, wetlands and water give the area high aesthetic appeal. It is one of the very few remaining large areas of open space within the State that has escaped intensive development.

2.72 Noise. Noise levels are ordinarily measured in units of decibels (dB), a term decribing the sound level on a logarithmic scale. A weighted decibel scale known as dBA more accurately represents noise levels as perceived by the human ear. Since noise

levels generally fluctuate over time, noise is frequently described statistically in terms of L_{10}, which is the sound level in dBA that is exceeded 10 percent of the time for the period under consideration.

2.73 The most prevalent noise source in urban/suburban areas such as Warwick and Cranston is automobile and truck traffic. Although arterial traffic volumes in the vicinity of the proposed local protection project are generally moderate, truck traffic on the major routes is substantial. Sound levels at a distance of 50 feet from an auto traveling 30 m.p.h are approximately 60 dBA. A full throttle diesel truck at the same distance can generate 90 dBA.

2.74 The Federal Highway Administration standards for residential areas specify that the 70 dBA level must not be exceeded over 10 percent of the time. Heavy automobile traffic or the frequent passage of large diesel trucks may cause noise levels in adjacent roadways to exceed tolerable levels.

2.75 The proposed construction activities in Warwick may generate significant noise from onsite construction equipment and heavy trucks traveling to and from the site. This type of activity would temporarily affect the aesthetics of the area.

2.76 Air Quality. The primary determinants of air quality in an area are the meteorological conditions and the nature of the sources of air pollutants. In the Warwick-Cranston area there are no longer industrial sources of significant air pollution. The primary source of contaminants is the burning of heating fuels in residential and commercial buildings. Another major cause of air pollution is the emission from vehicles traveling on the roadways in the area.

2.77 Present air quality was not determined in this study. However, it is likely that most locations generally experience favorable conditions since land use is predominantly medium density and vehicular travel on the arterial network is generally moderate.

2.78 In general, the air quality in the immediate vicinity of the considered projects is not expected to be significantly decreased during construction or after completion.

3.00 RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS

3.01 Area land use planners and the public are aware of the proposed flood protection plans. Several public meetings were conducted in addition to other meetings listed in the coordination section. As a result of our contact with State and local people, it is our understanding that the selected plan will have a positive effect on present and future land use plans. Flood protection may provide a potential increase in land area available for recreational and industrial use. Although these aspects are further addressed in the next section, the final decision regarding land use is a local responsibility.

3.02 In order to facilitate the evaluation of probable project impacts, the flood plain for the Standard Project Flood (SPF) in Cranston, Warwick, and West Warwick has been designated as a primary impact area. This is the land that would be most significantly protected by the proposed flood control measures (particularly the local protection project).

3.03 A substantial amount of land along the river in the SPF flood plain zoned for industry in all three municipalities with the following notable exceptions: (1) an area zoned for residential use on both sides of the river including the Norwood peninsula in Warwick and the residential area opposite it in Cranston; (2) wetland areas zoned for open space use in the Pawtuxet Reservation and the Pawtuxet River Reservation in the Pawtuxet and Eden Park sections of Cranston: (3) the commercially zoned area in Warwick west of the Warwick Industrial Park; and (4) the large area zoned for commercial use at the intersection of I-295 and I-95 (the location of Warwick Mall).

3.04 Not all of the riverside property that is zoned for development has been fully developed. Near the mouth of the river on the Warwick side, for example, land is available in the Warwick Industrial Park with the adjacent area zoned for commercial use and the next area also zoned for industry. Farther upstream, on the Cranston side, there is undeveloped industrially zoned land which will probably never be developed because it is an unsewered, low-lying wet area that the city intends to protect. In the Cranston residential area, opposite Warwick's Norwood section, land is available for additional residential growth.

3.05 Upstream of the Norwood peninsula there is undeveloped industrially zoned land on both sides of the river. Continuing upstream, there are areas zoned for industry up to the I-295 and I-95 intersection that are not completely developed. The commercially zoned area at the I-295/I-95 interchange also has land available for additional commercial uses. Almost all of the land in the West Warwick section of the study area is zoned for industrial use but, as previously noted, this area is not intensely developed.

3.06 Some of these areas may never be developed for their zoned use because of wetland areas that preclude development. The land in Warwick at the river's bend near the I-95 interchange with the airport access road characterizes this type of wetland area.

3.07 The land use in Coventry and West Greenwich will be significantly altered by the construction of the Big River Reservoir area that now is largely undeveloped will be transformed into an environment dominated by water. (The environmental impacts of including flood control storage at the reservoir will be addressed in the next section.)

4.00 THE PROBABLE IMPACT OF THE PROPOSED ACTION ON THE ENVIRONMENT

4.01 General. The primary impacts of the Selected Plan are: (1) a decrease in flooding, (2) the removal of vegetation and open space from along the Pawtuxet River, (3) the channelizing of a portion of the Pawtuxet River, (4) the removal of homes and evacuation of low-lying areas along the Norwood peninsula, and (5) the potential damage or destruction of vegetation and cultural resources surrounding the Big River Reservoir. The possibility of an increase in sedimentation was considered, but because of the Scituate Dam, the limited drainage basin and the numerous smaller dams throughout the tributaries of the river, this impact was forecast as minor.

4.02 The impacts of decreased flooding are beneficial and directly affect the human population. Implementation of the project would alleviate flooding and reduce local property damage. The dikes alone would increase flooding in Cranston, however, the flood storage at the Big River Reservoir would eliminate these increased flood stages with the net effect being no increased flooding. In the area of the Warwick Industrial Park a meander in the river would be channelized. The new channel would be located in an area currently open space and under State of Rhode Island's jurisdiction. The area of the current channel would be filled in and would be contiguous to industrial uses of the Warwick Industrial Park. Future use and development in this area would reflect local and State decisions.

4.03 In order to construct the Warwick Avenue Local Protection Project a large amount of vegetation adjacent to the river will have to be removed for the construction of walls and dikes. These structures will range in height an average of 10 to 18 feet and will extend for a distance of just over one mile. For the homes and businesses adjacent to the project there certainly will be a high degree of visual impact. To those properties inside the dike, this impact should be seen as a trade off to the flood protection that the project will afford.

4.04 Impacts on the Human Environment. Land Use. The proposed project would provide a moderate degree of flood protection for much of the land downstream from the Flat River Reservoir along the South Branch and the mainstem of the Pawtuxet River. Within the standard project flood plain, approximately 750 acres are currently vacant. There are about 475 acres zoned for industrial use, a minor amount for commercial use, and about 250 acres for residential use. (These land use figures are only applicable to zones 4-8 along the mainstem.)

4.05 Economic Impacts. Direct economic impacts that would result from the reduction of flood damages have been considered by the Corps in the benefit-cost analysis for the project. The indirect economic impacts resulting from the project are discussed here.

4.06 Present Corps estimates show that approximately 44 acres of vacant land would become more desirable for industrial development in and near the Warwick Industrial Park with flood protection since National Flood Insurance Program (NFIP) restrictions would be negated. In 1971 the Warwick Planning Department estimated that 44 acres of land in the industrial park, if protected from flooding, would be worth double or triple its then market value of $2.4 million. This corresponds to a value of more than $160,000 per acre. The city estimated that protection of the industrial park would create 1780 additional jobs, generating a payroll increase of $13.9 million annually.

4.07 Also protected would be 5 acres of commercial land and approximately [illegible] acres of residential land in the area immediately west of Warwick Avenue along the Pawtuxet.

4.08 Cranston. Future development plans as described in the Comprehensive Plan Report prepared by the city of Cranston Planning Department in 1975 emphasize the preservation and maintenance of riverfront areas for conservation and recreational purposes. A relatively large commercial area exists in the westernmost part of the Pawtuxet section that could be more fully developed. The Ciba Geigy Chemical Plant occupies most of the available industrial land in the easternmost portion of Park View, leaving little other land for development. The Howard Industrial Park occupies most of the Pettaconsett's riverfront, but it has experienced only limited flood problems.

4.09 West Warwick and Coventry. Although the proposed project would provide protection to the riverfront industrial and commercial developments along the Pawtuxet, it is doubtful that the project would significantly affect economic growth in West Warwick and Coventry.

4.10 Construction Impact. The regional economic impact of the project, due to increased construction and associated local supplies of material, would be positive. Earnings from the project would also positively affect the local economy through the multiplier effect of spending and investment. Short-term impacts during construction periods will primarily be noise from heavy construction equipment at the site and trucks moving to and from work areas. Air quality should not be significantly affected.

4.11 Traffic and Related Impacts. The traffic impacts of the project would be primarily short-term, resulting from the construction. Its impacts on noise and air quality are also discussed in this section since they are closely related to the traffic impacts.

4.12 Assumptions were made for this statement about the duration of construction and the most likely paths to be taken by construction equipment.

4.13 Since 10-wheel dump trucks generate a noise level of approximately 90 dBA at a distance of 50 feet, it is likely that Federal highway noise standards for residential areas (L_{10} = 70 dBA) might be exceeded along the truck route and adjacent to the building site during much of the construction period. The L_{10} designation refers to the noise level that must not be exceeded more than 10 percent of the time.

4.14 Warwick Avenue Area. The increase in truck traffic from construction of the Warwick local protection dike would not cause a congestion problem on the surrounding arterials (with the exception of already congested Park Ave.), but it might cause a noticeable increase in noise levels. Most of the surrounding roadways carry more than 50 trucks per hour during the peak hour. The Warwick project would add approximately 10 trucks per hour for the duration of the construction.

4.15 Although the land use adjoining the surrounding arterial network is mixed, substantial residential areas as well as several schools are present in the vicinity. Where standards are not now exceeded, the additional trucking during construction could possibly raise noise levels above Federal standards along the access route. The corresponding air quality decline would be insignificant.

4.16 Long-term increases in industrial park traffic and related effects would probably occur as a result of the enhanced development potential of the area.

4.17 Norwood Area. Construction activities associated with evacuation of the area will be ongoing up until the time the Big River Reservoir is complete. Approximately 40 to 50 homes will be destroyed or relocated from low-lying areas on the peninsula. The residents living adjacent to the proposed site and along the access streets through the neighborhood would encounter some discomfort during the evacuation period from the dust and noise of truck travel and construction operations. These impacts, while of limited duration, would be locally significant but careful consideration to the use of local streets and thorough planning efforts should minimize these concerns.

4.18 Social and Cultural Impacts. No social or cultural resources such as churches or community facilities would be directly affected by the proposed selected plan. However, the construction and evacuation activities will most likely alter the character of Norwood to some degree when homes and families are displaced.

4.19 Warwick Avenue Area. Once these areas are fully protected, it is possible that new employment opportunities could be created by industrial development in the flood plain. An increase in the supply of jobs could lower the area's unemployment rate

and/or attract new residents to the vicinity. All of the municipalities in the study area show a projected growth rate and appear to be preparing for future anticipated population increases by extending utility systems, preserving land for open space, etc.

4.20 Social disruptions due to an influx of new residents are unlikely to occur since the residential locations of the new workers would undoubtedly be widely dispersed. The number of new jobs that would be created as a result of the new development is relatively small compared to the amount created by other recent or anticipated employment generators in the study area such as the Warwick Mall and the Howard Industrial Park.

4.21 Norwood Area. There are both positive and negative social impacts that would result with the implementation of the Norwood Land Bank. Presently, homes abutting the river or ones in low-lying areas get flooded during periods of heavy rain. In the past ten years, on no fewer than four occasions 30 to 40 families had to be evacuated from their homes by truck or boat. Like past experiences, future floods would require that electric service to the area be shut off until the water recedes. This potentially creates a severe health and safety hazard. Basements and cellars are all but useless, with boilers and furnaces constantly needing repair or replacement. Residents who are vulnerable to flooding become quite fearful when heavy rains are forecast. Relocation of these homes would relieve the residents of such frequently occurring hardships. The major negative social impact of this plan would be the relocation of 40 to 50 families from their homes. In some cases relocation of the present structure to another site could be accomplished. In other cases, though, the families would have to find new homes in a different neighborhood. The stress associated with loss of home could be significant in this neighborhood which is characterized by a rather stable, blue-collar population. Removal of structures would occur over several years, with completion contingent on construction of the Big River Reservoir.

4.23 Impacts to Cultural or Archaeological Resources. Coordination with the Rhode Island Historic Preservation Commission, undertaken in 1976 indicated no effects upon significant cultural resources as a result of the project for the Warwick Industrial Park (Warwick Avenue Area).

4.24 The Big River Reservoir component does not appear to affect significant cultural resources, beyond those which may be impacted by construction and management of the water supply aspects of the reservoir. Further studies of the reservoir will be undertaken if Congress authorizes the project to proceed into more advanced design stages. Coordination with the Rhode Island Historic Preservation Commission will be maintained throughout the Big River study.

4.25 Impact on Recreation Resources. The proposed flood control measures will have little or no impact on existing recreational resources within the project area. The proposed improvement would prevent flooding in most of the lands within the impact area that currently offer recreational amenities, however, this would not increase the number of days that these lands would be available for recreational use.

4.26 Other losses or gains are less definite. Commercial or industrial development generated as a result of increased flood protection may pre-empt opportunities for the recreational use of certain flood plain areas. This is evident especially in the area of the proposed channelization works near the Pawtuxet Reservation. In the absence of flood control measures, this land would be best suited for less intense uses such as recreation or conservation.

4.27 New recreation opportunities could possibly be created with the construction of the project dikes. Bike paths or pedestrian walkways could be designed if the residents of local communities expressed an interest in them. In certain areas the dikes and walls would not directly abut the river, leaving the existing flood plain open for possible passive recreation use.

4.28 The effect of flood control storage at Big River Reservoir on recreation will be minimal. Only passive recreation occurs in the area now. Very likely this trend would remain when the reservoir is completed due to the water supply aspect.

4.29 Impacts on the Physical and Natural Environment.

Construction Impacts. The construction would cause some adverse visual and physical impacts of both a temporary and permanent nature. The presence of construction machinery, temporary structures and fenced storage and stockpile areas will detract from the project area.

4.30 In order to construct the walls and dikes, a substantial amount of native and ornamental plant material will have to be destroyed. At areas such as Geigy Chemical, the project will change the character of the area by the removal of large trees adjacent to the river. In the area near the Pawtuxet Reservation, the natural appearance will be altered substantially when channelization work is undertaken.

4.31 Aesthetic Impacts. The primary aesthetic impact of the proposed project would be the appearance of the flood control dikes and walls and their obstruction of views.

4.32 Warwick Avenue Area. The local protection facility proposed for the Warwick Industrial Park area involves more than

6,500 linear feet of walls and dikes. In light of the present industrial and commercial uses of the area, it is unlikely that the project would detract significantly from the site. The land side of the dike will be grassed and this should help in visually blending into the park area.

4.33 From the Cranston side of the river, the project would obstruct views of the industrial park. The aesthetic experience, though, would not be enhanced since the concrete walls and rock faced dike would be in sharp contrast to the natural riverbank and lands of the Pawtuxet Reservation.

4.34 Norwood Area. The evacuation and construction activity in this area will significantly impact the site. The most apparent impact will be from trucks and heavy equipment. There will be increased noise, dust, and traffic congestion. The visual quality of the site will be lessened significantly during the years of evacuation. Once all the homes have been moved, the area will be regraded, seeded and left in a natural state. There is a possibility of park development in this area, but this will be left to the city of Warwick for consideration.

4.35 Big River Reservoir. There will be virtually no negative visual impacts resulting from implementation of flood control storage at the reservoir. Negative impacts may result if vegetation dies as a result of long periods of inundation. At present there is no way to calculate if and when such events will occur.

5.00 PROBABLE ADVERSE ENVIRONMENTAL IMPACTS THAT CANNOT BE AVOIDED

5.01 Following are some of the unavoidable adverse impacts that might result from the proposed flood control project in the Pawtuxet Basin. Short- and long-term impacts will be dealt with separately.

5.02 Several major short-term impacts are associated with the construction of the project. There would be increased traffic on the surrounding roadways, primarily from trucks hauling material to the construction site. While their number would not be too great for the roads to handle, the large, slow moving trucks could be expected to hamper traffic flow.

5.03 Noise and Air. The large trucks carrying materials could be expected to increase noise levels adjacent to roadways in the construction areas, adversely impacting on the comfort of residents. The construction processes and grading operations at the construction sites would also increase noise levels and add dust to the air in the immediate area.

5.04 There will be an increase in the turbidity of the Pawtuxet River as a result of the construction activities. This would have a negative impact on aquatic life in the river. This decrease in water quality would only be short-term and would improve significantly once construction was completed.

5.05 A large amount of plant material would be destroyed during construction. This loss will be evident especially in the industrial complex of Geigy where large hardwoods will have to be cut down for the construction of concrete walls. The clearing of vegetation will have both short-term and long-term impacts. Long-term impacts will result with the removal of large, mature trees since it will take many years for new trees to replace them.

5.06 There will be several other long-term impacts of the proposed project. Approximately 40-50 homes will be removed from the Norwood peninsula resulting in long-term social and economic impacts for these familieis.

5.07 The straightening and filling of the river near the Warwick Industrial Park will have long-term impacts to both aquatic and terrestrial habitat and recreation opportunities. Approximately three acres of riverbed will be filled in and five acres of the Pawtuxet Reservation Conservation land will become part of the industrial park. Also, riparian habitat will be lost throughout a substantial length of the project, resulting in the demise of a segment of small mammal and invertebrate populations associated with this habitat. Where possible, a buffer zone of vegetation will be left to serve as cover for birds and larger mammals.

6.00 ALTERNATIVES TO THE PROPOSED ACTION

6.01 Formulating a Plan. Principal water resource problems within the basin are the need for flood management measures, phased development of public water supplies and water quality improvement measures. Alternative solutions for satisfying flood control needs are evaluated in this section. Water supply and water quality improvement measures have been the subject of previous and ongoing studies by the Rhode Island Water Resources Board and the Rhode Island Statewide Planning Program, respectively.

6.02 Key Steps in the Plan Formulation. In formulating a well-balanced flood management plan for the Pawtuxet River Basin, a series of basic formulation steps were used in the screening or evaluation process to determine the best alternative plan. Figure VI-1 is a flow chart of the plan formulation screening process. The following key steps were used:

6.03 Potential Measures. All possible regulatory and corrective measures for meeting the flood protection needs of the basin were identified and briefly appraised. A No Action Program (one entailing no Corps of Engineers participation) was considered throughout the plan formulation process. It assumes that all communities would control growth within their flood plains, at least to meet the minimum requirements of the ongoing National Flood Insurance Program (NFIP). The NFIP provides a Federal subsidy to private insurers so that flood-prone properties may be eligible for flood insurance.

6.04 When a community enrolls in the emergency program, its residents and business owners/operators become eligible for low cost subsidized rates up to the amounts available in the table listed on the next page. After completion of the flood insurance study, final publication of the Flood Insurance Rate Maps and enactment of the local flood plain zoning required under this program, the municipality is enrolled in the regular program. In essence the zoning requires that all new construction and substantial improvements to existing structures in HUD identified flood-prone areas be elevated or floodproofed to the level of the hundred-year flood.

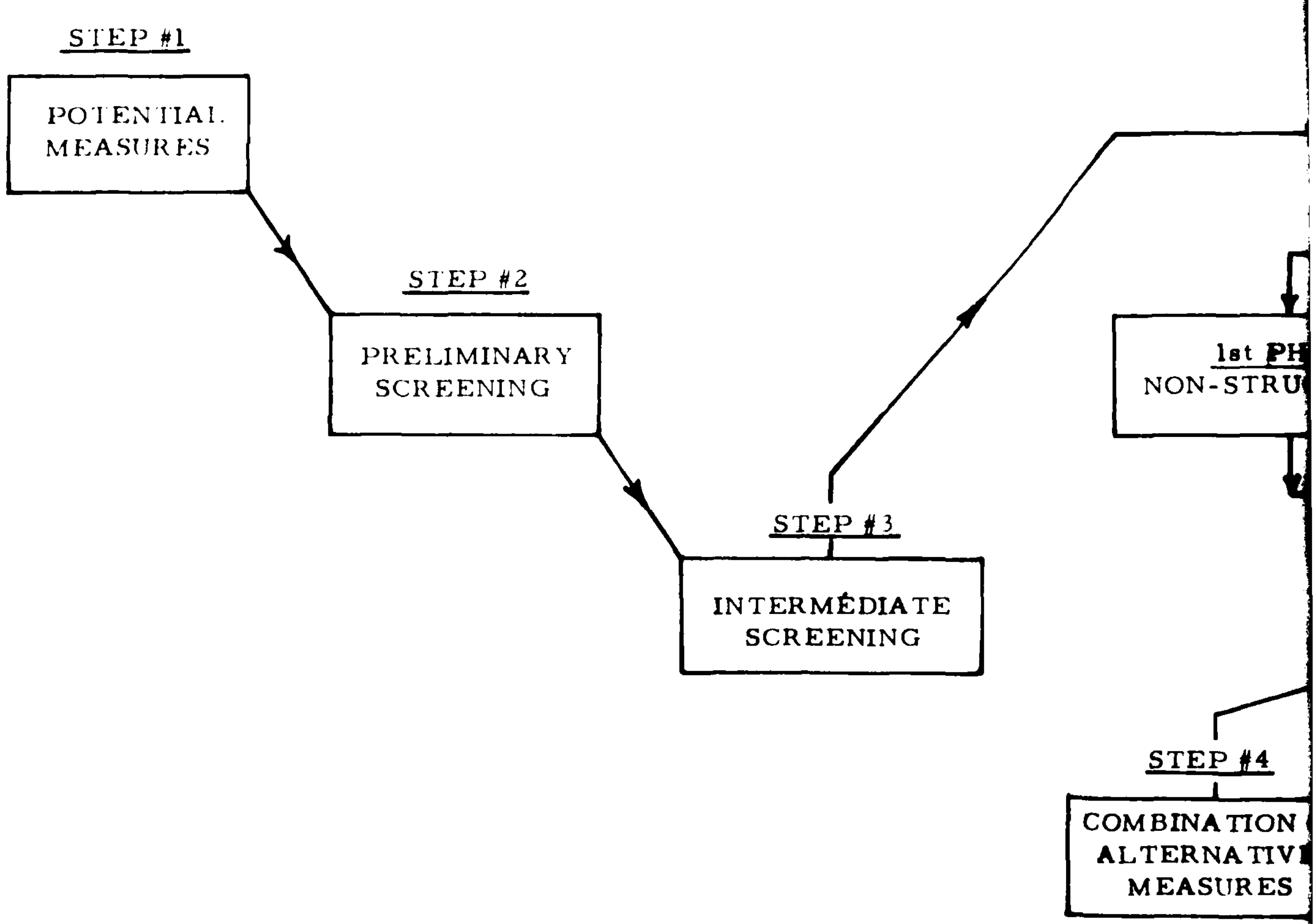
6.05 The regular program makes available a second layer of insurance coverage, also listed on the next page. However, the insuree must pay the so-called acturial rates. These have been established by building types, zone classification, and relationship of the structure to the 100-year flood level.

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
FEDERAL INSURANCE ADMINISTRATION
NATIONAL FLOOD INSURANCE PROGRAM

	Emergency Program		Regular Program			
	Total Amount Available (First Layer)[1]	Subsidized Rate of $100 of Coverage	Second Layer	Acturial Rate Per $100 Coverage Based on Risk	Total Amt Available 1st & 2nd Layers[2]	Max Required
Single Family Residential	$35,000	$.25	150,000	Rate Varies With Risk	185,000	70,000
Other Residential	100,000	.25	150,000	Rate Varies With Risk	250,000	200,000
Contents Residential	10,000	.35	50,000	Rate Varies With Risk	60,000	20,000
Small Business	100,000	.40	150,000	Rate Varies With Risk	250,000	200,000
Contents Small Business	100,000	.75	200,000	Rate Varies With Risk	300,000	200,000
Other Nonresidential	100,000	.40	100,000	Rate Varies With Risk	200,000	200,000
Contents, Other Nonresidential	100,000	.75	100,000	Rate Varies With Risk	200,000	200,000

(Limits required under Section 102(a)(b) of Act of 1973)

PLAN FORMULATION FLO



FLOW CHART

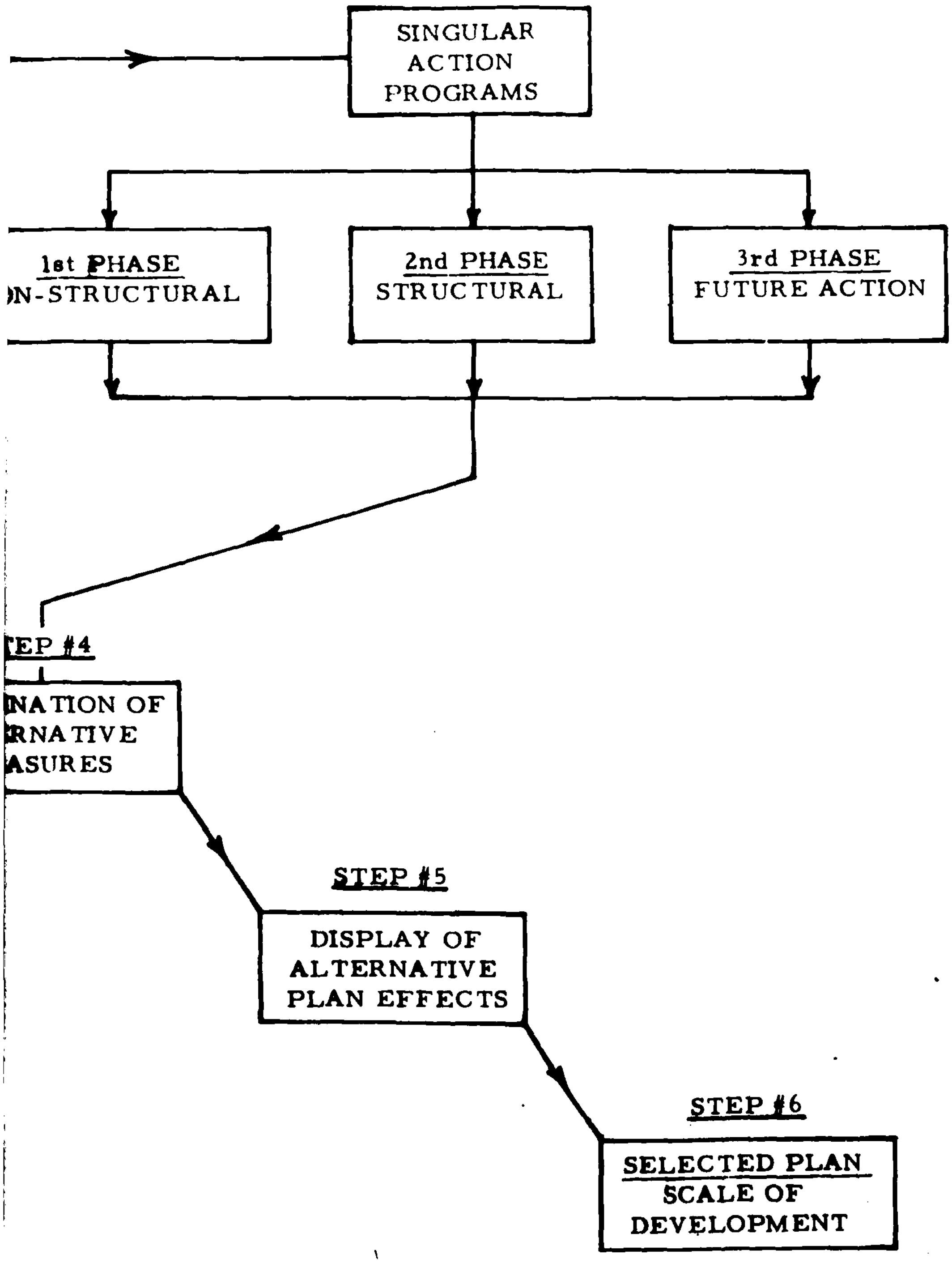


FIGURE VI-1

6.06 In addition to the No-Action Plan, a number of regulatory and corrective measures are summarized on Table VI-1. Regulatory measures discourage the use and development of flood plains, lessening the threat of flood damage and possible loss of life. Corrective measures would include the physical construction of structures such as reservoirs, walls and dikes, hurricane barriers and stream improvements (channelization). Other activities would include the flood proofing or relocation of homes.

6.07 Initial Screening. In this step, all regulatory and corrective measures as well as a No-Action Plan were evaluated with engineering judgement and brief study for application in each of the 16 zones of the watershed (see Figure VI-2).

6.08 Each measure was judged on its own merits and those not considered adequate, realistic or practical engineering solutions were eliminated along with those measures found to be socially or environmentally unacceptable or economically unjustified. The No-Action Program and all regulatory measures were determined to be applicable to all 16 zones. Therefore, both programs were reserved for further evaluation in subsequent steps.

6.09 Corrective Measures. Extensive land treatment measures are not warranted as there are no major erosion problems within the basin. Should erosion problems occur, assistance is available under the existing authority of the Soil Conservation Service (SCS), Department of Agriculture.

6.10 Reservoirs at numerous sites within the study area were investigated. Most of the sites were found to be either too small to provide economically justified protection or were not acceptable because of engineering, social or environmental constraints.

6.11 Modification of Scituate Reservoir, presently used only for water supply purposes, was found to be economically unjustified. Although this reservoir has played a substantial role in reducing flood stages and resultant damage in the past. It is managed exclusively to optimize its water supply capabilities. To utilize Scituate Reservoir for flood control purposes would require either raising the existing structure an additional 10 feet or providing a subimpoundment within the reservoir. The costs of either project would far exceed the benefits to be derived by downstream communities from flood damage reduction.

6.12 Walls and Dikes can provide effective flood protection to high risk flood-prone areas where numerous structures vulnerable to high flood losses are located. Seven zones in the basin meet these high risk conditions and wall and dike measures were retained for further evaluation in these zones.

6.13 Reservoir Management Programs entail lowering the levels of existing reservoirs to reduce peak flood discharges. With the exception of Scituate and Flat River Reservoirs, further investigation of the smaller reservoirs in the basin was deemed impractical because of the limited storage capacities involved.

6.14 Hurricane Barriers to eliminate tidal flooding under storm conditions were considered for both the entrance to Pawtuxet Cove and the head of the cove where the river discharges. Excessive costs and adverse social and environmental impacts eliminated these projects from further investigation.

6.15 A barrier at the river mouth would involve the total reconstruction of Pawtuxet Dam, huge pumping facilities, river widening, relocation of numerous industrial, commercial and some residential structures and modifiction of six bridges and several local roads. These costs would far exceed benefits.

6.16 Stream Improvements to correct long neglected channel conditions which have caused an alarming deterioration of the hydraulic efficiency of some of the basin's major streams were considered for the following major elements:

1. Removal of dams, particularly those small dams within the basin originally intended for power generation and now neglected and obsolete, proved to be economically infeasible.

2. Diversion of flood flows to bypass heavy damage zones were considered. Intrabasin schemes were evaluated and none seemed viable. An interbasin scheme diverting floodwaters to Apponaug Cove has been retained for further evaluation.

3. Channel modification to improve streamflow by either channel widening, deepening or realignment proved to be economically or hydraulically impractical.

6.17 Flood Proofing and Relocation was found to warrant further evaluation in all zones except 1, 2, 3, 4A, and 7A, where the flood problems were determined to be minimal.

6.18 Conclusions. A high percentage of the corrective measures proposed in the potential measures available section failed to meet the minimum acceptable plan requirements in the preliminary screening process and were therefore eliminated. Twenty-three possible solutions were deemed worthy of more detailed analysis. As previously noted, all regulatory measures as well as the No-Action Plan have been retained for further analysis.

TABLE VI-1

POTENTIAL MEASURES

NO ACTION PROGRAM
(See Text for Definition)

REGULATORY MEASURES

1. National Flood Insurance Program

2. Flood Plain Regulations
   a. Encroachment Lines
   b. Zoning
   c. Subdivision Regulations

3. Land Use Programs

4. Other Regulatory Measures
   a. Building Codes
   b. Urban Redevelopment
   c. Tax Adjustments
   d. Warning Signs
   e. Health and Fire Regulations
   f. Cleanup Campaign
   g. Flood Forecasting

CORRECTIVE MEASURES

1. Land Treatment Measures

2. Reservoirs

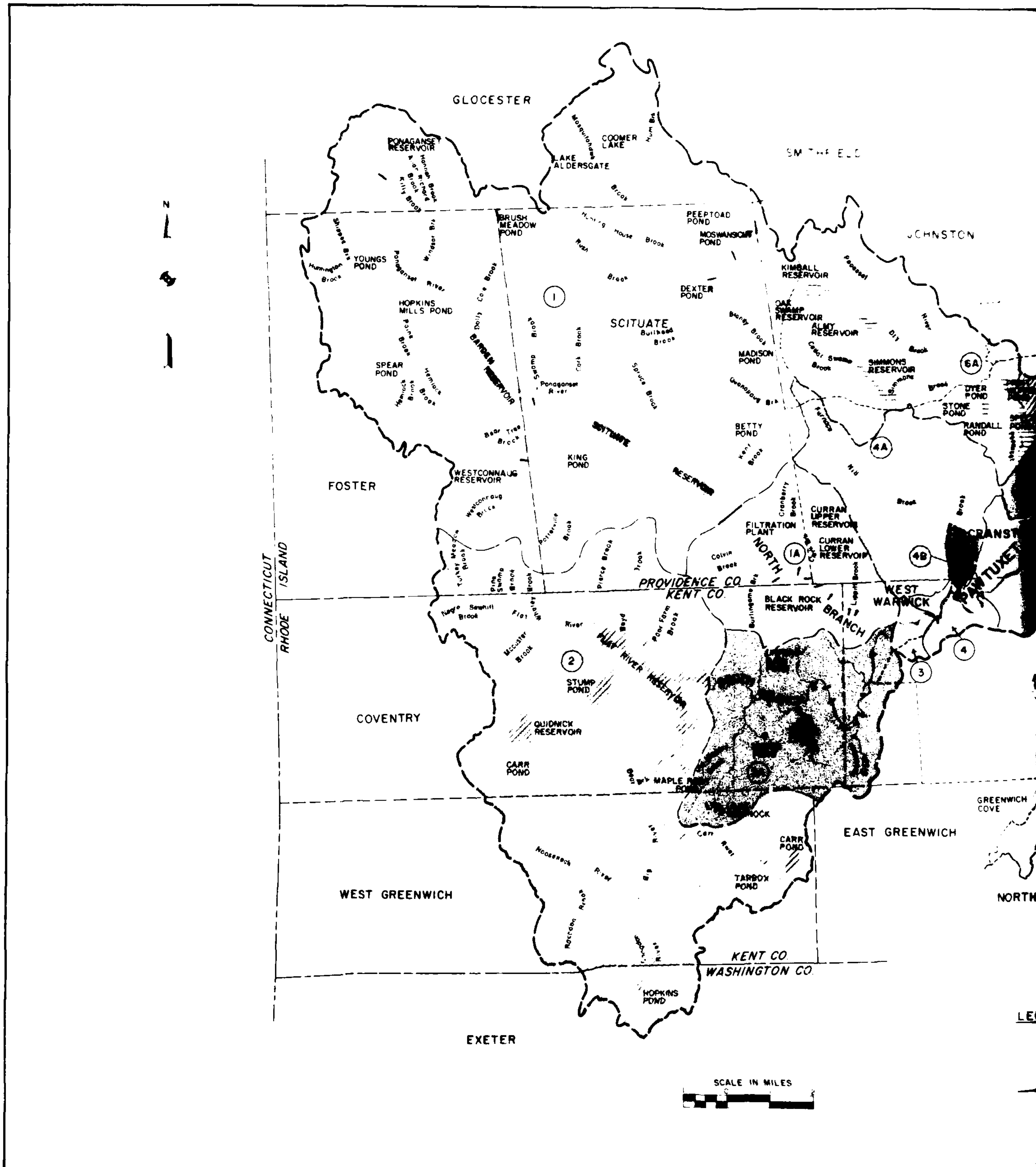
3. Walls and Dikes

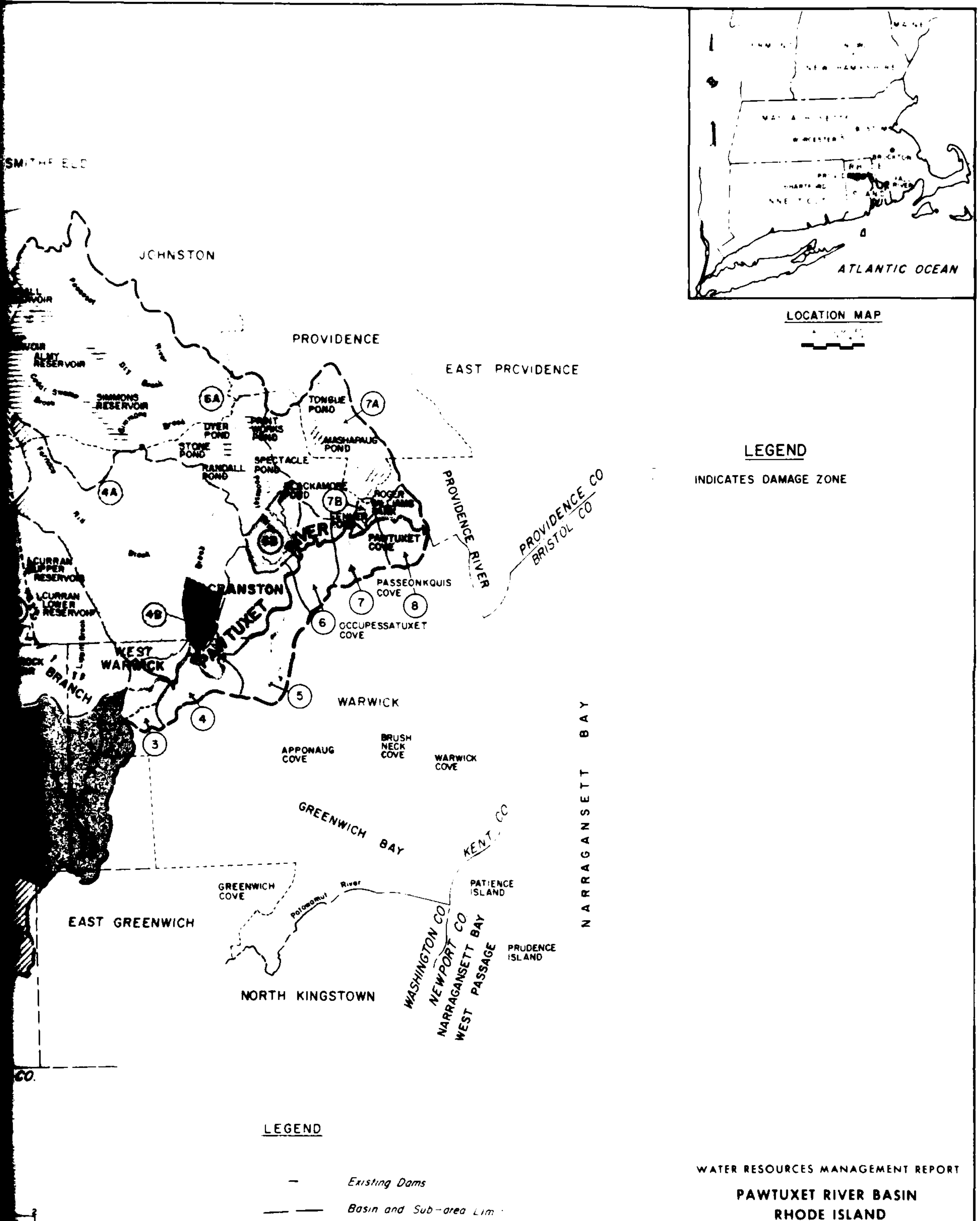
4. Reservoir Management Programs

5. Hurricane Barriers

6. Stream Improvements
   a. Channel Modification
   b. Modification or Removal of Dams
   c. Diversion of Flood Flows

7. Floodproofing or Relocation


N
GLOCESTER
SMITHFIELD
JOHNSTON
PONAGANSET RESERVOIR
COOMER LAKE
LAKE ALDERSGATE
PEEPTOAD POND
MOSWANSICUT POND
BRUSH MEADOW POND
YOUNGS POND
HOPKINS MILLS POND
SPEAR POND
KIMBALL RESERVOIR
DEXTER POND
OAK SWAMP RESERVOIR
ALMY RESERVOIR
SCITUATE
MADISON POND
SIMMONS RESERVOIR
DYER POND
STONE POND
RANDALL POND
BETTY POND
KING POND
SCITUATE RESERVOIR
BARDEN RESERVOIR
WESTCONNAUG RESERVOIR
FOSTER
FILTRATION PLANT
CURRAN UPPER RESERVOIR
CURRAN LOWER RESERVOIR
NORTH BRANCH
PROVIDENCE CO.
KENT CO.
CONNECTICUT
RHODE ISLAND
BLACK ROCK RESERVOIR
WEST WARWICK
PAWTUXET
STUMP POND
FLAT RIVER RESERVOIR
QUIDNICK RESERVOIR
COVENTRY
CARR POND
MAPLE ROOT POND
EAST GREENWICH
GREENWICH COVE
CARR POND
TARBOX POND
WEST GREENWICH
KENT CO.
WASHINGTON CO.
HOPKINS POND
EXETER
SCALE IN MILES
1
1A
2
3
4
4A
4B
6A



WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

DAMAGE ZONES

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

FIGURE VI-2

TABLE VI-2

INITIAL SCREENING

POTENTIAL MEASURES	1	1A	2	2A (2A-1+2)	3	4	4A
NO ACTION PROGRAM	E	E	E	E	E	E	E
REGULATORY MEASURES (ALL)	E	E	E	E	E	E	E
CORRECTIVE MEASURES							
Land Treatment Measures	5	5	E	5	5	4	4
Reservoirs	1	5	E	5	1, 2, 3	1, 2, 3	1
Walls & Dikes	5	1	5	1	5	E	1
Reservoir Management Program	E	4	E	4	4	5	4
Hurricane Barriers	6	6	6	6	6	6	6
Stream Improvements							
Removal of Dams	5	4	4	4	5	2	4
Diversion of Flood Flows	4	1	4	1	2	E	1, 2
Channel Modification	5	5	5	5	5	1, 3	1, 3
Flood Proofing or Relocation	5	E	5	E	5	E	5

CRITERIA APPLIED DURING SCREENING

1. Economically Infeasible
2. Engineeringly Impractical
3. Socially Unacceptable
4. adequate Solution
5. No Major Needs or Problems
6. Not Applicable

DAMAGE ZONES

North Branch --------- 1-1A
South Branch ---------- 2-2A
Main Stem------------ 3-8
Meshanticut Brook ---- 4A-4B
Pocasset River ------- 6A-6B
Roger Williams Brook - 7A-7B

NING

ZONES										
4	4A	4B	5	6	6A	6B	7	7A	7B	8
E	E	E	E	E	E	E	E	E	E	E
E	E	E	E	E	E	E	E	E	E	E
4	4	4	4	4	4	4	5	5	5	4
1, 2, 3	1	1	1, 2, 3	1, 2, 3	1	1	1, 2, 3	5	2	1, 2, 3
E	1	1	E	E	1	E	E	5	E	E
5	4	4	4	4	1	4	4	1, 3	4	2
6	6	6	1, 2, 3	1, 2, 3	6	1, 2, 3	1, 2, 3	6	1, 2, 3	1, 2, 3
2	4	6	6	6	3, 4	6	6	3, 4	6	4
E	1, 2	1, 4	2	2	1	1	2	1, 4	2	2
1, 3	1, 3	1, 3	1	1	1, 3	1, 3	1, 3	5	1, 3	1, 3
E	5	E	E	E	E	E	E	5	E	E

LEGEND

- 1-1A
- 2-2A
- 3-8
- 4A-4B
- 6A-6B
- 7A-7B

E	Further Evaluation Warranted
#	Further Evaluation Unwarranted

6.19 Intermediate Screening. Those measures which passed the preliminary screening were further analyzed to see if they could provide an adequate degree of protection in major damage areas while meeting the established criteria.

6.20 The first element of this evaluation process consisted of a nonstructural program of regulatory and corrective measures that were analyzed in depth in accordance with the desires of local citizens. A structural program was then evaluated and future action measures were considered.

6.21 Corrective Nonstructural Program. Flood proofing, a major component of this program, involves techniques to make existing buildings and their contents less vulnerable to flood damages. To determine the viability of flood proofing in zones 3-8, costs were developed for all structures for both 100-year and Standard Project Flood, about 616 existing structures--33 percent of those located in the SPF area--would require relocation. Eighty-three of the structures requiring relocation are commercial or industrial, with about 5,700 employees. At the 100-year flood level, approximately 26 structures would have to be relocated, of which 14 are commercial or industrial firms employing about 2,500 people.

6.22 Cost figures indicate that flood proofing alone, without other flood protection measures in combination, would not meet the benefit-cost criterion and would be economically prohibitive and socially and environmentally undesirable.

6.23 In other zones, preliminary evaluation indicated that the costs of flood proofing alone would far exceed benefits.

6.24 Therefore, flood proofing as an independently used measure was rejected as not satisfying benefit-cost criteria. It has been retained, however, for further consideration in combination with other measures.

6.25 Structural Program. Two types of structural flood management programs were considered to protect heavily urbanized areas in the flood plain along the lower end of the main stem.

6.26 Two systems of dikes, walls, and channel modification were evaluated, one to protect against the Standard Project Flood, the other against the lower level of the 100-year flood. These are designated, respectively, as Alternative Plans A and A-1.

6.27 Alternative A would require 13 individual local protection projects in three communities at a 1978 cost of $60 million. This scheme provides protection only to individual units or small groups. The costs for lands and damages and interior drainage

facilities were excluded; if included, the total cost of this alternative could double. Analysis showed that the plan as a total unit would not be economically justified although two local projects--Warwick and Bulova--warranted further investigation.

6.28 Alternative A-1 entailed the same projects but at a lower level of flood protection. Once again, the total plan did not meet benefit-cost criteria, but the local projects at Warwick and Bulova were economically justified. Alternate A-1 would cost a total of $30 million dollars in 1978, excluding lands and damages and interior drainage facilities.

6.29 Both Alternative A and A-1 were rejected, but the two economically justified local projects were retained for further evaluation.

6.30 Two alternate diversions of floodwaters were also evaluated:

1. The Pontiac Diversion project considered four different alignments, but each proved to be unjustified because of social, economic or environmental constraints.

2. The Natick Diversion, with its intake 10,000 feet farther upstream to a point just below the Natick Dam, was the other alternative considered. It was found to provide a high degree of protection to existing and future downstream development at a lower cost and was economically justified. Therefore, this diversion has been reserved for further evaluation.

6.31 Future Action. Three future action programs to be implemented by local interests could strengthen the flood management program for the Pawtuxet River Basin: reservoir construction, reservoir management and land treatment measures.

1. Construction of the Big River Reservoir as a potential water supply for metropolitan Providence could provide significant downstream flood protection at minimum cost by increasing the height of the proposed dam by about 2.5 feet. This would give additional flood control storage equivalent to about six inches of runoff over a drainage area of about 30 square miles.

2. Management of the Scituate and Big River Reservoirs in conjunction with each other presents an opportunty to optimize the operations of both reservoirs so that each could provide floodwater storage capability without jeopardizing its principal purpose, water supply.

3. Erosion control measures should be instituted by local interests during construction of the Big River Reservoir in coordination with programs of the Soil Conservation Service.

6.32 <u>Conclusions.</u> Although nonstructural flood proofing was found to be economically infeasible as a single action program, it was retained for further consideration as a supplement to the Natick Diversion and the Bulova and Warwick local protection projects, which warranted further consideration. Reservoir construction, reservoir management and erosion control during reservoir construction were retained as future action programs for each alternative selected for inclusion in the system of accounts. The No-Action and regulatory measures programs were also retained for further evaluation, as supplements to specific corrective measures.

6.33 <u>Combination of Alternative Measures</u>. A number of alternative flood management plans were evaluated consisting of various combinations of previously discussed single action measures, in addition to the consideration of a No-Action Plan based on the availability of the National Flood Insurance Program. Table VI-2 summarizes these alternative plans.

6.34 From previous analysis it was apparent that only the main stem zones 4-8 would be the subject of any further detailed studies for any corrective measures, other than a potential reservoir site at Big River. There were no single action corrective measures that passed the intermediate level of screening for the many tributary streams, other than that previously mentioned. The remainder of the planning process dealt with the derivation of detailed costs, benefits, environmental studies and evaluation of various flood control systems combining corrective, corrective non-structural and regulatory measures.

6.35 <u>Alternative A</u>. This alternative would consist of the Natick Diversion, with a 30-foot diameter tunnel. With Natick Diversion as the only structural component, substantial flood loss reductions would be realized in the main stem zones and in the tributary zones affected by backwater conditions. Residual losses along the main stem would be reduced by this scheme to an average annual loss slightly more than $800,000.

6.36 Implementation of the 30′ diversion reduces the number of ownerships affected by a 100-year flood event from 471 to 266, and for an SPF event from 1,856 to 959. In addition, the diversion also provides a substantial reduction in water depths in the 266 ownerships still subject to residual flooding by a 100-year flood event. A component of this alternative would be the future action elements consisting of flood control storage at Big River Reservoir and the regulation/management of Scituate Reservoir. When combined with the 30′ diameter Natick Diversion to act as a system the proposal would

be economically justified due to the low separable costs of the flood control element. The additional net benefits along the South Branch and the main stem would result in a system of B/C ratios of about 1.1 to 1. The additional flood stage reduction at events ranging from about a 100-year event down to the common yearly type flood would remain the same as the diversion is capable of discharging the floodwaters. However, at events rarer than the one percent flood stage reduction of one half a foot up to one foot is possible depending upon the zone and the flood event.

6.37 Alternative B. This alternative would consist of Natick Diversion with a 30' diameter tunnel and the Warwick Avenue and Elmwood Avenue local protection projects. From the various local protection measures evaluated as single action measures a plan evolved that would provide local protection measures for extreme northeastern Warwick, extending from the lower limits of Zone 6 and including all damaged portions of Zones 7 and 8. A series of dikes, floodwalls and other structures would provide full protection, to SPF event as modified by Natick Diversion, to the residential-commercial area in the vicinity of Elmwood Avenue (U.S. 10 and the Warwick Industrial Park and adjacent residential-commercial area in the vicinity of Warwick Avenue (RI 1170).

6.38 Provision of the Natick Diversion and the Elmwood Avenue-Warwick Avenue protective measures would reduce average annual losses in the lower basin to approximately $235,000 with the 30-foot diameter tunnel project. With the 30-foot diameter diversion tunnel and the Warwick protective measures, most of the residual losses would occur within the Cranston portions of Zones 4B, 6, 7, and 8, but no protective measures for these Cranston areas proved to be economically justified. The remaining losses in Warwick Zones 4, 5, and 6 and the West Warwick portion of Zone 4 would be minimal following reductions by the Natick Diversion.

6.39 Local protection measures for the Bulova Watch Company industrial complex in Zone 5, which had been determined to be marginally justified as a single action measure were reconsidered in combination with the Natick Diversion. With the 30-foot diameter diversion tunnel, flood stages would be substantially reduced so that flood damages at the Bulova complex would be minimal. At the 100-year flood level only the lower floor of the main office building would be subject to flooding. Under such conditions, the use of sandbags at the building entrances and adequate interior pumping facilities could eliminate interior flood losses. Therefore, it was determined that local protection measures acting in conjunction with Natick Diversion would not be economically justified at the Bulova industrial complex.

6.40 To summarize, only three structural measures were found to be economically justified when acting as a unit: the Natick

TABLE VI-3

OWNERSHIPS SUBJECT TO FLOODING
FOLLOWING PROVISION OF 30' DIAMETER
NATICK DIVERSION
(Zones 4-8)

Community/ Category	100-year flood Natural Conditions	100-year flood Following Diversion	Standard Project Flood Natural Conditions	Standard Project Flood Following Diversion
Warwick				
Commercial	21	9	44	29
Industrial	14	8	19	16
Residential	151	109	569	194
Public	2	1	2	2
Schools	0	0	1	1
Others	3	0	3	3
Sub-total	191	127	638	245
Cranston				
Commercial	11	10	27	17
Industrial	6	4	16	7
Residential [1]	354	207	1,083	613
Public	3	3	8	6
Schools	2	2	2	2
Others	2	1	5	4
Sub-total	378	227	1,141	649
West Warwick				
Commercial	8	1	11	10
Industrial	4	1	5	4
Residential	41	2	53	48
Public	1	1	1	1
Schools	1	0	3	1
Others	1	0	3	1
Sub-total	56	5	76	65
Totals	625	359	1,855	959

[1] Figures for backwater flooding on the Pocasset River and Meshanticut Brook from the Pawtuxet River are included. These figures were based upon preliminary hydrologic evaluations. Recently available data indicates that the affective residences would be significantly less, resulting in a much lower degree of reduction.

Diversion and local protection measures for the Elmwood Avenue-Warwick Avenue area of Warwick (Warwick Local Protection).

6.41 As summarized in Table VI-3, implementation of Alternate B (Natick Diversion with 30-foot diameter tunnel and Warwick Local Protection) would reduce the number of ownerships affected by the 100-year flood level from 471 to 148.

6.42 Another component of this alternative would be the future action elements consisting of flood control storage at Big River Reservoir and the regulation/management of Scituate Reservoir. When combined with the above system, a benefit to cost ratio of slightly above unity would be realized.

6.43 Alternative C. This alternative would consist of Natick Diversion with a 21′ diameter tunnel and the Warwick Avenue-Elmwood Avenue local protection projects. The series of dikes, floodwalls and other structures are the same as above. However, the walls and dikes are several feet higher than those considered in Alternative B. Both local protection projects were justified as single action measures in the intermediate level of detail and combined in a plan above.

6.44 Provision of the Natick Diversion and the Elmwood Avenue-Warwick Avenue protective measures would reduce average annual losses in the lower basin to approximately $522,000 with the 21-foot diameter tunnel project. With the 30-foot diameter diversion tunnel and the Warwick protective measures, most of the residual losses would occur within the Cranston portions of Zones 4B, 6, 7, and 8, but no protective measures for these Cranston areas proved to be economically justified. The remaining losses in Warwick Zones 4, 5, and 6 and the West Warwick portion of Zone 4 would be minimal following reductions by the Natick Diversion.

6.45 Local protection measures for the Bulova Watch Company industrial complex in Zone 5, which had been determined to be marginally justified as a single action measure in this intermediate screening were reconsidered in combinations with the Natick Diversion. With the 21-foot tunnel as with the 30-foot diameter diversion tunnel, flood stages would be substantially reduced so that flood damages at the Bulova complex would be minimal. Therefore, it was determined that local protection measures acting in conjunction with Natick Diversion would not be economically justified at the Bulova industrial complex.

6.46 Another component of this alternative would be the future action elements consisting of flood control storage at Big River Reservoir and the regulation/management of Scituate Reservoir. When combined with the above system, a benefit to cost of ratio slightly above unity would be realized.

6.47 Alternative D. This alternative would consist of the same two local protection projects discussed previously - the Warwick Avenue Local Protection and the Elmwood Local Protection Projects.

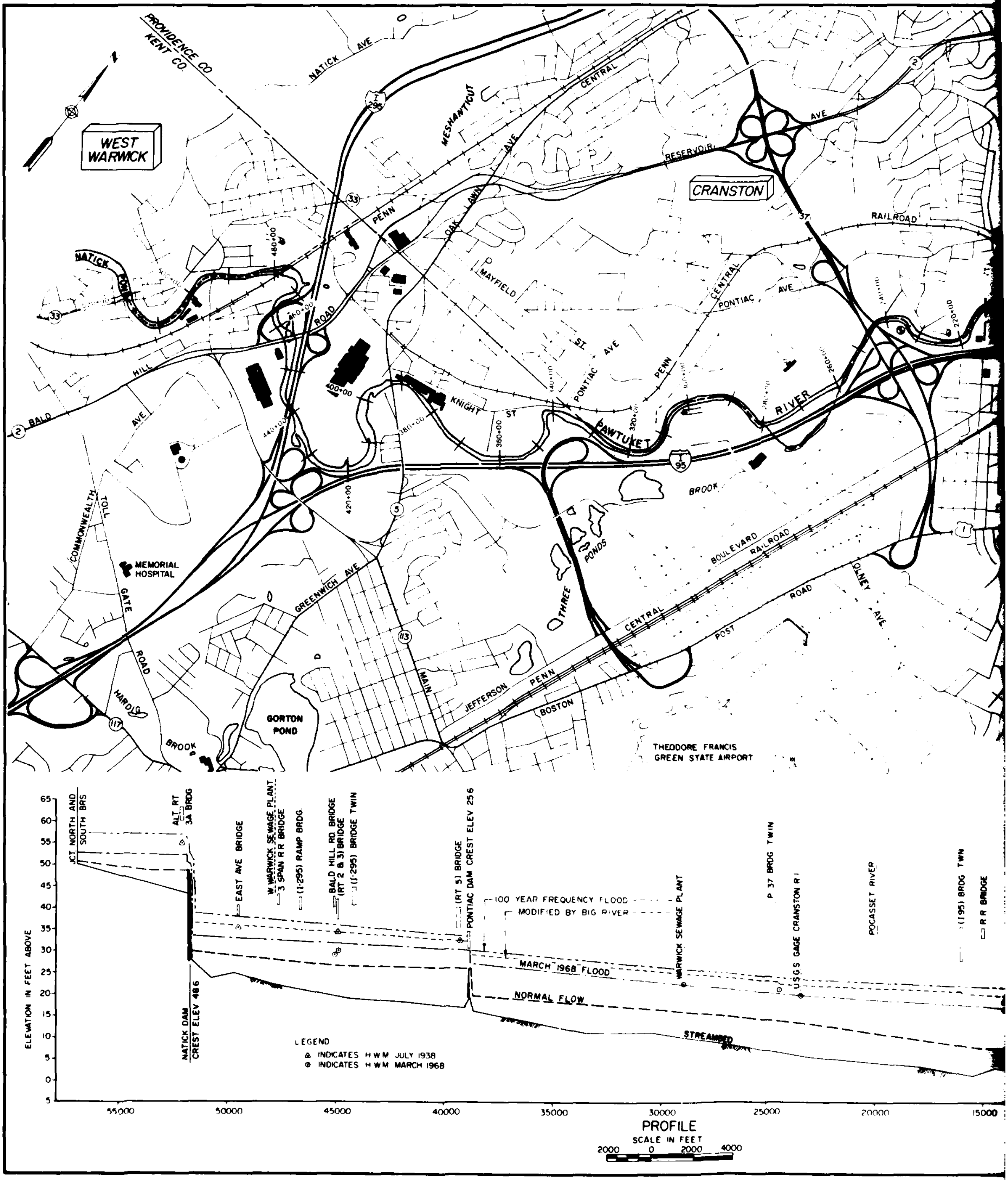
6.48 The protective measures evaluated for the combined Elmwood Avenue-Warwick Avenue area would protect the same area of Warwick (Zones 7, 8, and part of Zone 6) as considered in the intermediate screening level. However, the project was evaluated in greater economic and engineering data. Protection of this Warwick area to the SPF level was determined to be economically justified. The Warwick local protection project would provide a benefit of about $1,450,000. While the local protection project for comparative purposes would protect 150 ownerships that are subject to flooding at the 100-year flood level, it is standard practice to design Corps local protection projects to the SPF level to avoid the false sense of security that could result from lower levels of protection. Therefore, the Warwick local protection project would protect 450 ownerships: 9 industrial, 21 commercial and 420 residential.

6.49 The estimated costs for the projects, evaluated as a system were $1,131,000 on an annual basis. The overall systems benefit to cost ratio is 1.28 to 1.0 excluding the area redevelopment benefits.

6.50 Another component of this alternative would be the future action elements consisting of flood control storage at Big River Reservoir and the regulation/management of Scituate Reservoir. As an element of this system, the project would have a benefit to cost ratio in excess of 1.15 to 1.0.

6.51 Alternative E. This alternative consists of the addition of flood control storage at the proposed Big River Water Supply Reservoir. The project would be built by non-Federal interests. The plan would also consist of a management/regulation of both Scituate and Big River to help reduce flood stages by allowing some flood water storage at Scituate without losing any water supply potential. As Big River would be designed for flood control, management of this reservoir is less critical.

6.52 Benefits for the flood control increment at Big River are realized in all downstream zones from the confluence of Big River and the South Branch down to and including Zone 8. The total annual benefits for all zones combined amounts to be about $620,000 excluding any growth. Figures VI-3 and VI-4 show the flooded areas at the 100-year flood and standard project flood. The profiles accompanying these plates show the reductions that can be expected with flood control storage at the Big River Reservoir.



PROVIDENCE CO
KENT CO.
WEST WARWICK
CRANSTON
NATICK AVE
MESHANTICUT
CENTRAL AVE
RESERVOIR AVE
OAK LAWN AVE
PENN
RAILROAD
NATICK POND
ROAD
BALD HILL AVE
MAYFIELD ST
PONTIAC AVE
PENN CENTRAL
KNIGHT ST
PAWTUXET RIVER
BROOK
THREE PONDS
BOULEVARD
RAILROAD
OLNEY AVE
POST ROAD
CENTRAL
PENN
JEFFERSON
BOSTON
MAIN
GREENWICH AVE
COMMONWEALTH AVE
TOLL GATE ROAD
MEMORIAL HOSPITAL
HARDIG BROOK
GORTON POND
THEODORE FRANCIS GREEN STATE AIRPORT
480+00
460+00
440+00
420+00
400+00
380+00
360+00
340+00
320+00
300+00
280+00
260+00
240+00
220+00
JCT NORTH AND SOUTH BRS
ALT RT 3A BRDG
EAST AVE BRIDGE
W WARWICK SEWAGE PLANT
3 SPAN R R BRIDGE
(I-295) RAMP BRDG.
BALD HILL RD BRIDGE (RT 2 & 3) BRIDGE
(I-295) BRIDGE TWIN
(RT 5) BRIDGE
PONTIAC DAM CREST ELEV 25.6
100 YEAR FREQUENCY FLOOD
MODIFIED BY BIG RIVER
WARWICK SEWAGE PLANT
P 37 BRDG TWIN
USGS GAGE CRANSTON R I
POCASSET RIVER
(I95) BRDG TWIN
R R BRIDGE
MARCH 1968 FLOOD
NORMAL FLOW
STREAMBED
NATICK DAM CREST ELEV 48.6
ELEVATION IN FEET ABOVE
LEGEND
△ INDICATES H W M JULY 1938
⊕ INDICATES H W M MARCH 1968
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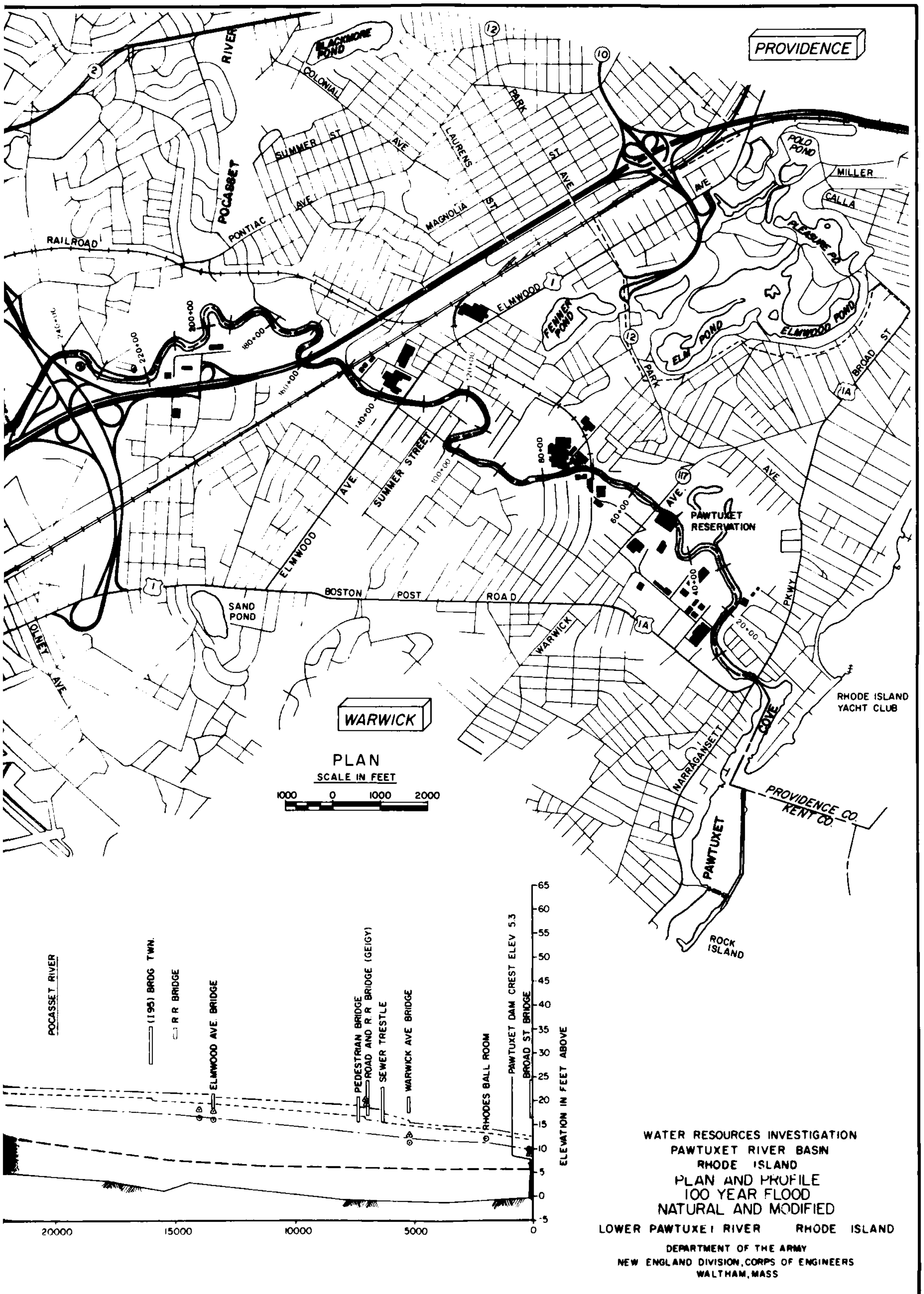
PROVIDENCE
BLACKMORE POND
COLONIAL
PARK
LAURENS
SUMMER ST
AVE
POCASSET
RIVER
PONTIAC AVE
MAGNOLIA ST
ST AVE
RAILROAD
POLO POND
MILLER
CALLA
PLEASURE RD
ELMWOOD
FENNER POND
ELM POND
ELMWOOD POND
PARK
BROAD ST
SUMMER STREET
ELMWOOD AVE
PAWTUXET RESERVATION
AVE.
AVE
PKWY
BOSTON POST ROAD
SAND POND
OLNEY AVE.
WARWICK
RHODE ISLAND YACHT CLUB
COVE
WARWICK
NARRAGANSETT
PROVIDENCE CO.
KENT CO.
PAWTUXET
ROCK ISLAND
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SCALE IN FEET
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100+00
80+00
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20+00
POCASSET RIVER
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R R BRIDGE
ELMWOOD AVE. BRIDGE
PEDESTRIAN BRIDGE
ROAD AND R R BRIDGE (GEIGY)
SEWER TRESTLE
WARWICK AVE BRIDGE
RHODES BALL ROOM
PAWTUXET DAM CREST ELEV 5.3
BROAD ST. BRIDGE
ELEVATION IN FEET ABOVE
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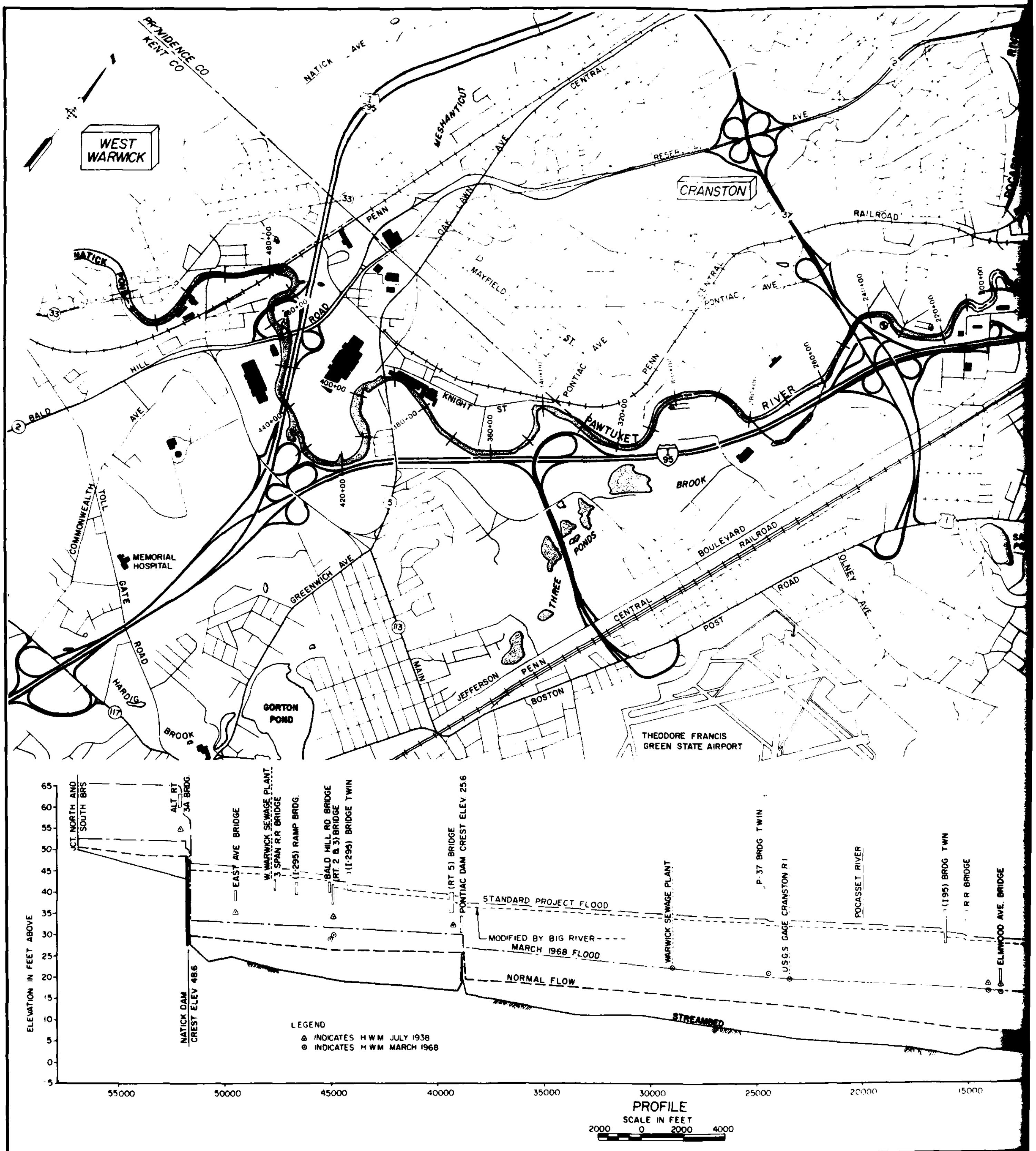
WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND
PLAN AND PROFILE
100 YEAR FLOOD
NATURAL AND MODIFIED
LOWER PAWTUXET RIVER RHODE ISLAND
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

FIGURE VI-3



WEST WARWICK
CRANSTON
PROVIDENCE CO
KENT CO
NATICK AVE
MESHANTICUT
CENTRAL
RESERVOIR AVE
RAILROAD
PENN
OAK LAWN AVE
MAYFIELD
PONTIAC AVE
ST.
KNIGHT ST
PAWTUXET RIVER
BROOK
THREE PONDS
NATICK POND
BALD HILL ROAD
COMMONWEALTH AVE
TOLL GATE ROAD
MEMORIAL HOSPITAL
GREENWICH AVE
MAIN
HARDIG BROOK
GORTON POND
JEFFERSON
BOSTON
CENTRAL RAILROAD
BOULEVARD
POST ROAD
OLNEY AVE
THEODORE FRANCIS GREEN STATE AIRPORT
480+00
460+00
440+00
420+00
400+00
380+00
360+00
340+00
320+00
300+00
280+00
260+00
240+00
220+00
200+00
ELEVATION IN FEET ABOVE
JCT. NORTH AND SOUTH BRS
ALT RT 3A BRDG.
NATICK DAM CREST ELEV 48.6
EAST AVE BRIDGE
W. WARWICK SEWAGE PLANT
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(I-295) BRIDGE TWIN
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STANDARD PROJECT FLOOD
MODIFIED BY BIG RIVER
MARCH 1968 FLOOD
NORMAL FLOW
STREAMBED
WARWICK SEWAGE PLANT
RT 37 BRDG TWIN
USGS GAGE CRANSTON R I
POCASSET RIVER
(I 95) BRDG TWIN
R R BRIDGE
ELMWOOD AVE. BRIDGE
LEGEND
INDICATES HWM JULY 1938
INDICATES HWM MARCH 1968
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PROFILE
SCALE IN FEET
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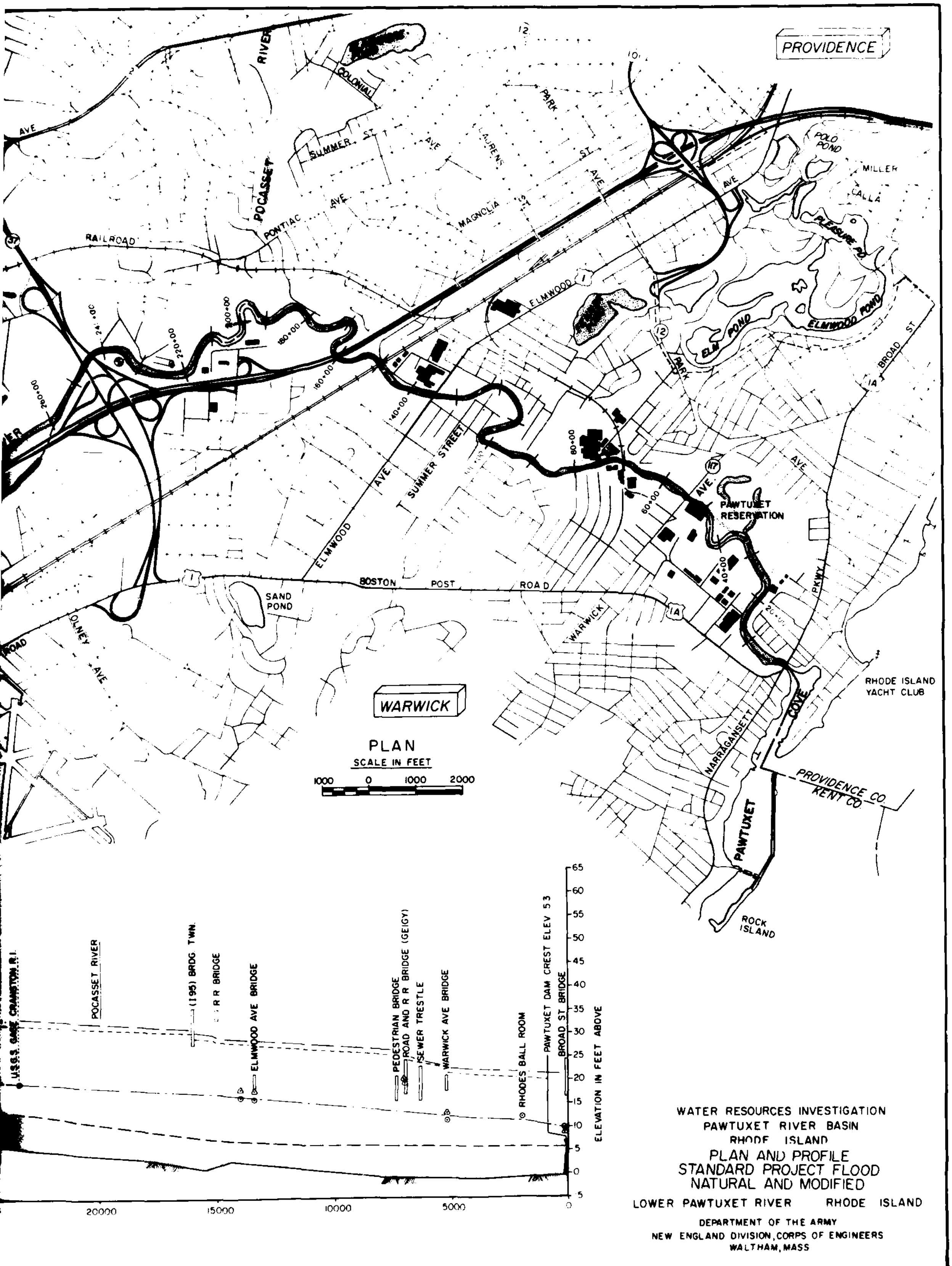

PROVIDENCE
WARWICK
PLAN
SCALE IN FEET
1000 0 1000 2000
POCASSET
RIVER
COLONIAL
SUMMER ST
PARK
LAURENS
AVE
MAGNOLIA
PONTIAC
RAILROAD
ELMWOOD
POLO POND
MILLER
CALLA
PLEASURE RD
ELM POND
ELMWOOD POND
BROAD ST
SUMMER STREET
PAWTUXET RESERVATION
BOSTON POST ROAD
SAND POND
OLNEY
WARWICK
NARRAGANSETT
PKWY
COVE
RHODE ISLAND YACHT CLUB
PROVIDENCE CO.
KENT CO.
PAWTUXET
ROCK ISLAND
U.S.G.S. GAGE CRANSTON, R.I.
POCASSET RIVER
(195) BRDG TWN.
R R BRIDGE
ELMWOOD AVE BRIDGE
PEDESTRIAN BRIDGE
ROAD AND R R BRIDGE (GEIGY)
SEWER TRESTLE
WARWICK AVE BRIDGE
RHODES BALL ROOM
PAWTUXET DAM CREST ELEV 53
BROAD ST BRIDGE
ELEVATION IN FEET ABOVE
20000
15000
10000
5000
0
WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND
PLAN AND PROFILE
STANDARD PROJECT FLOOD
NATURAL AND MODIFIED
LOWER PAWTUXET RIVER RHODE ISLAND
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

FIGURE VI-4

6.53 The project, as mentioned previously, is not justified as a single purpose flood control dam but when considered as a component of the major water supply purpose is justified for flood control when cost-allocated. The overall B/C ratio is about 1.4 to 1.0

6.54 Alternative F. This alternative would consist of the No-Action program--one that local interests would implement in the absence of a corrective Federal assistance program. It is assumed that local interests would institute a program for controlling growth within the 100-year flood plains, at least the minimum zoning controls required for eligibility in the National Flood Insurance Program. The plan would be equally applicable to both main stem zones and all major tributary streams.

6.55 As this alternative would exclude the consideration of structural components, reduction in flood stages for alleviating damages in flood-prone areas would be unattainable. Some intensification of flood problems could be expected in varying degrees because of continuing urbanization within the basin with the program. If the No-Action program is not implemented as a minimum program, flood problems are expected to magnify over the years.

6.56 This alternative includes the only means available for compensating losses due to flooding, through municipal and individual participation in the National Flood Insurance Program. However, flood losses would be only partially covered as there are no existing provisions for compensating policy holders for non-physical losses, such as expenses for lodging during dwelling rehabilitation or loss of income or profit while a commercial or manufacturing firm is temporarily closed. In addition, the uninsured would receive no monetary compensation; such a condition could result if all municipalities do not participate in the National Flood Insurance Program. Without strict adherence to the provisions of the National Flood Insurance Program, which includes the requirement that flood plain zoning to the 100-year event be instituted, future flood losses along the main stem alone would far exceed $5,000,000 annually, including new development that could be expected during the next 25 years at a conservative growth rate. These estimated losses to potential growth development within the flood plains, in excess of $2,000,000 annually, are based on analysis and projections of past development trends in the flood plains.

6.57 Alternative G. This alternative consisted of the 21 foot diameter Natick Diversion tunnel and the Warwick Avenue local protection. This alternative is the same as Alternative C except that the Elmwood Avenue local protection has been dropped from consideration. With our protection scheme, the estimated costs are $4,000,000. The total benefits or damages prevented are equal to

$4,300,000, resulting in the benefit to cost ratio of 1.08 to 1.0. Because this system has the overall highest benefit to cost ratio it is designated as the National Economic Development (NED) plan.

6.58 A late stage public meeting was held in Warwick on October 14, 1976. At that time the Corps recommended plan was Alternative B. There was a definite lack of support for this plan primarily for two reasons. Many local people thought that the cost was too high and that there were too many unanswered questions concerning the environmental effects of diverting flood waters into Apponaug Cove and Narragansett Bay. Since there was support that something should be done, further studies were then conducted to come up with a publically acceptable plan.

6.59 About this same time it became evident that the State of Rhode Island was interested in the Corps of Engineers as the planner-designer of the Big River project, and if justified and environmentally acceptable, construct the complex. This necessitated a more accurate hydrological determination as to effects downstream created by the Big River Reservoir impoundment. Although final answers were not available, and in order to expedite as much as possible the already delayed project report, a final stage public meeting was held on May 19, 1977.

6.60 A new plan, Alternative H, was presented at the meeting. It consisted of local protection projects at Elmwood Avenue and Warwick Avenue. Another component of this plan consisted of implementing flood control storage at the Big River Reservoir, which would be constructed by the Corps. Since detailed river stage reductions afforded by Big River were not yet available it was not known what the exact heights of the local protection projects would be. The public was informed that the Corps would continue to study this point.

6.61 After thorough investigation it was learned that the Elmwood Avenue project would need to be raised by one to two feet higher than originally planned in conjunction with Big River. In order to raise and stabilize the dike at Elmwood Avenue a 20-foot wide berm would be necessary. This modification greatly increased the cost of the project and resulted in its not being economically justified. Even though the area is warranted some form of protection, a local protection project would far exceed the costs even with potential environmental (social) tradeoffs. Thus, any further consideration for a local protection project for the Elmwood Avenue area based on updated costs cannot be considered.

6.62 The second plan evolving from the reformulation, Alternative I, consists of the multi-use Big River Reservoir, the Warwick Avenue local protection and a proposal, called the Norwood Land Bank, whereby the most flood-prone homes in the Elmwood Avenue area

would be purchased by Federal interests. The same non-structural alternatives as considered with all the previous plans would also be applicable to this scheme. The elevations of the Warwick Avenue protection would be the same as that considered under the previous alternative. The difference is that the consideration for a local protection project for Elmwood Avenue has been replaced by a proposal for outright purchase of 33 homes. As also with the previous alternative, Big River would be planned, designed and if economically and environmentally justified built by the Corps of Engineers.

6.63 The benefits attributed to the Warwick Avenue local protection and Big River Reservoir are the same as has been calculated under the previous alternatives. The benefits for the Norwood Land Bank consist of determining the annual residual losses to the affected homes after modification from Big River Reservoir. The annual damages are then converted to a present worth value using a fifty year life and the prevailing interest rate of 6 and 5/8 percent. The benefits are only considered for events up to a .5 percent natural event, approximately equal to a one percent event after modification by Big River Reservoir's flood storage. The total systems benefits are equal to $2,058,000 as shown below.

Benefits to Big River	$ 725,000
Benefits to Warwick Avenue	$1,173,000
Benefits to Norwood Land Bank	$ 160,000

The total annual cost for the protection system is $1,3[illegible]5,000. Thus, the total benefit to cost ratio is 1.56 to 1.0.

6.64 Alternative J. Current regulations and review requirements necessitate the presentation of a non-structural plan among the final alternative plans. Non-structural measures include flood proofing, relocation, and regulatory measures to minimize flood loss. As regulatory and future action measures are included in other alternatives, flood proofing and relocation will be addressed alone for this alternative.

6.65 Flood proofing consists of those adjustments to structures which are designed or adopted primarily to reduce visiting flood damages. These adjustments usually consist of barriers on windows and doors; a watertight membrane surrounding interior walls, and interior drainage control. A number of other flood proofing schemes are also possible. Relocation would be required when the potential flood waters exceed the limits of the flood proofing.

6.66 The governing regulation for determining benefits on non-structural measures for relocations is contained in ER 1105-2-353. Most of the traditional type annual damages cannot be claimed as a benefit if either relocation or evacuation is planned. The only

allowable means for claiming benefits consists of determining the net income earned by activities occupying the flood plain with the project plus that portion of the flood damages reduced by the project which is not borne by the non-flood plain occupants. Structures such as Ciba-Geigy, the Warwick Mall, the Warwick Industrial Park, Bulova, the Pontiac Print Works Building and the Jefferson Avenue Industrial Park cannot realistically be either flood proofed or relocated. Most of these buildings are slabs on grade type of construction with concrete block wall construction and extensive use of glass fronts/windows. With the heights of water to be encountered the block walls and/or glass cannot be flood proofed necessitating relocation according to the intent of the regulations. At the Ciba-Geigy complex an additional fallacy of the flood proofed requirements is evident. Many of the first floods, as well as subfloors are inundated for the complex housing about twenty plus major structures. Most range in size between six to ten stories. They presently need expansion for increased production. However, they do not have any available land to expand upon. If they would be forced to eliminate usage of the flood damaged floors, they could conceivably move elsewhere. This would cost the local community roughly 1000 jobs. The same can be said of some of the above areas. In addition to the loss of jobs created by the flood plain evacuation, a large increase in taxes would be necessary to offset the new vacant lands.

6.67 The firms and areas mentioned in the preceding paragraphs constitute over 90 percent of the existing flood damages. Summarizing, it is not logical nor practical, nor economically feasible to flood proof or relocate these elements. However, in compliance with current requirements the non-structural plan is included in the Systems of Accounts (detailed analysis can be found in the Main Report and Technical Appendices). As is evident, the plan falls far short of the required benefit to cost criteria necessary for project implementation. Thus, consideration of this measure cannot be recommended for Federal involvement.

6.68 Display of Alternative Plan Effects - System of Accounts. This is a graphical presentation of the alternatives selected in the previous step. It provides a technique to reflect the adverse and beneficial effects of each alternative so that these effects can be readily discerned and tradeoffs between alternative plans compared. It analyzes the alternatives by geographic region for their resultant effects on National Economic Development (NED), Environmental Quality (EQ), Social Well-Being (SWB) and Regional Development (RD).

6.69 A detailed description of this step can be found in Appendix 2 of the Technical Appendices to the Main Report.

6.70 Selection of the Best Alternative Plan. Ten alternative plans were developed, but because of the duration of the plan formulation and screening processes several plans either lack the required economic justification or were not acceptable to local interests. Those alternatives that included the Natick Diversion (A, B, C, & G) were not acceptable because of possible adverse impacts to Apponaug Cove. Alternatives D and H included a local protection project at Elmwood Avenue (Norwood). After detailed analysis it was determined that the latter project was not viable from a benefit-cost point of view.

6.71 The plan that provides the largest net NED benefits to the largest portion of the watershed is Plan G consisting of a 21-foot diameter Natick Diversion tunnel and the Warwick Avenue local protection project. Also considered would be the non-structural elements such as participation in the National Flood insurance Program, the future action program, and the addition of 6" of flood control storage onto the Big River Water Supply reservoir to be built by non-Federal interests. As such this plan is called the NED plan and provides the highest degree of protection at the least cost to the largest area. The previously recommended NED plan (October 1976) was Alternative B.

6.72 Environmental impacts vary according to alternatives. Once again, Alternatives A, B, C, & G had potentially harmful impacts to Apponaug Cove, and were unacceptable to local people. Adverse impacts for environmental quality would occur during the construction phases for any of the structural plans presented in the system of accounts (Appendix 2 of the Technical Appendices to the Main Report). Of all the alternative plans, Alternative I is the one that is the least disruptive to the environment and as such is the EQ (Environmental Quality) plan. (Plan J, the non-structural plan, is not a viable alternative).

6.73 All displayed structural alternatives have positive impacts under the Social Well-Being account. The impacts are the most favorable for Alternative B (30-foot diameter diversion tunnel and the two Warwick local protection projects. They afford the highest security possible against flooding). The major significant negative impact would apply to Alternative B, D, H, I and J where significant relocations would be required. Alternative B would require seven relocations, D-6, H-approximately 10, I about 40, and J about 40-54. Although Plan D is no longer feasible because of the subsequent foundations investigations and limited reduced heights due to the Big River Reservoir complex. The homes to be relocated under Plan I are those that have been or are subject to major flooding potential in the Norwood peninsula area. All plans considering the Natick Diversion will require the taking of one home at the intake structure.

6.74 Although construction in an urban area is normally a negative social impact, analysis by this office in the impacted area did not prove this to be true. The people and establishments adjacent to the proposed walls and dikes are subject to constant flooding and hardships. They generally view the construction activities, i.e., the increased noise, traffic etc,. as a short term loss, and in exchange they are gaining a lifetime protection against the flood threats which have constantly interfered with their normal operations.

6.75 Under the Regional Development account, all structural measures would have positive impacts. Construction activities would produce many new jobs and increase spending in the area. The industrial and commercial establishments along the river would be afforded a high, if not complete, degree of protection against flooding, and that could induce them to expand their operations. As they expand, more permanent type jobs would be created. All of the anticipated land growth or urban factors would conform with the proposed land use and zoning criteria currently available from the impacted municipalities.

6.76 Of the ten alternative plans the one that best provides the needed flood protection and is responsible to local demands is Alternative I. It is also the plan that is least disruptive to the natural environment, and as such is designated as the EQ plan.

7.00 THE RELATIONSHIPS BETWEEN LOCAL USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF PRODUCTIVITY

7.01 The flood protection afforded by the project will significantly reduce potential flood damages to existing structures located along the river. This is an immediate short-term enhancement.

7.02 The long-term productivity of the project area will be affected by the proposed plan. The loss of riparian habitat will reduce the long-term productivity of wildlife along the river. New development in flood protected areas will also have an effect on productivity. This development should be regulated at a local level so that it conforms to comprehensive land use plans. Furthermore, this development should be environmentally sound. Economic development versus conservation and recreational land use is an issue which should be determined at the local level.

7.03 The Pawtuxet River is one of the most important environmental resources in central Rhode Island. For many years it has been polluted and largely neglected. However, in recent years, projects for the control of pollution and the treatment of effluents have improved the Pawtuxet's water quality. The continuation of these projects will make the river a valuable environmental resource for recreation, fish and wildlife and aesthetic enjoyment.

8.00 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

8.01 Implementation of the proposed project would result in the irreversible and irretrievable commitment of various resources in the region. Concrete, rock and earth fill would comprise the bulk of material resources that would be needed to construct the project. Earth fill and concrete are available in sufficient quantities and would not become scarce because of the project. Rock would have to be obtained from quarries in the region.

8.02 The loss of approximately 20 acres of riparian habitat will be cleared for the walls and dikes, which would be an irreversible commitment of one land use to another. Furthermore, the loss of conservation land in the Pawtuxet Resevation resulting from channelization would now be land that could be committed to another use as determined by local authorities. A net loss of approximately 24,000 square feet of stream habitat and 1200 feet of potential streambank access would also result from channelizing the river.

9.00 COORDINATION

9.01 The Governor of Rhode Island designated the Rhode Island Water Resources Board as the official State liaison for the Pawtuxet River Study. Primary coordination with Rhode Island State and local interests were made through that office.

9.02 Direct contact has been made with the State Historic Preservation Officer and his staff. Site reconnaissance archaeological surveys, including an underwater survey of the floor of Apponaug Cove, were made.

9.03 To afford citizens, municipal and State officials and representives of other Federal agencies an opportunity to present their views and desires concerning the need and extent of flood reduction measures and other interrelated water-oriented resources, four pubic hearings were held at the initiation of the study on 9, 12, 15, and 22 May 1969. Though these four public hearings were intended to cover the entire Pawcatuck River and Narragansett Bay Drainage Basin (PNB) study area, as mandated by seven Congressional Resolutions, two of these hearings were held in Providence and Kingston, Rhode Island--two areas contiguous to the Pawtuxet River Basin.

9.04 All interested parties were invited to be present or represented at these hearings, including representatives of Federal, State, county and municipal agencies/and those commercial, industrial, civic, highway, railroad, water transportation and flood control interests and concerned property owners. They were afforded full opportunity to express their views concerning the character and extent of the improvements desired and the need and advisability of their execution. The sponsors of improvement measures were urged to present pertinent factual material bearing upon the general plans of improvement desired and to give detailed supporting data on the economic justification of the undertaking. Opposing interests were also urged to state the reasons for their position.

9.05 Subsequent to those meetings, approximately 20 informal meetings were held with State and municipal interests and approximately 25 informal meetings were held with concerned citizens. Informal contacts with key Federal and State agences and approximately 20 field contacts also furthered the progress of the studies.

9.06 Two plan formulation public meetings were held on 6 and 8 May 1975 Warwick and Cranston, Rhode Island, respectively. The purpose of these meetings was to present all of the alternative plans developed during the investigation and to incorporate public desires in plan formulation and choice of the most desirable alternative. Subsequent to these meetings, nearly 100 field contacts were made, several informal meetings were held with

citizens groups, approximately 20 informal contacts were made with State and municipal interests and nearly 50 informal contacts were made with Federal environmental and fishery interests.

9.07 During the fall of 1976, a draft of the Pawtuxet River Study was released for public review and presented at a public meeting on 14 October. Accompanying the report was a draft Environmental Impact Statement. At that time the Selected Plan included the Natick Diversion and the Warwick Avenue Local Protection Project, and the Elmwood Avenue Local Protection Project supplemented by future measures. Since there was lack of local support for the Selected Plan, other studies were conducted that would involve less cost and less impact on Apponaug Cove.

9.08 A final public meeting was held on 19 May 1977 to present plans to the public. At that time, Alternate D, which consisted of the local protection projects at Elmwood Avenue and Warwick Avenue, Big River Reservoir and future measures would yield less flood protection than Alternate B (Natick Diversion) but it would cost less and would have no impact on Apponaug Cove. Those attending responded favorably to the Corps' pursuing plans toward implementing Alternate D.

9.09 After detailed studies it was found that Alternate D was not implementable due to economic reasons. The Elmwood Avenue LLP was not economically justified.

9.10 A revised Selected Plan (Alternate I) was then developed. This alternate included a proposal for a Norwood Land Bank which would give assistance to flood prone residents near Elmwood Avenue. Included in this alternate plan was the local protection project at Warwick Avenue and flood control storage at the Big River Reservoir along with future measures.

10.0 COMMENT AND RESPONSE

When the Draft EIS was released in 1976 the selected plan included the Natick Diversion, which would have transferred flood waters from the Pawtuxet River through a tunnel and finally emptying into Apponaug Cove and Greenwich Bay. This element of the selected plan was not acceptable to the public, which voiced its opposition at a Public Meeting in October, 1976, in Warwick. The major concerns about the diversion centered on the high costs and possible adverse environmental impacts to Apponaug Cove and the shellfish industry if freshwater were mixed with the salt water in the cove. Numerous letters on the Draft EIS opposed the diversion. Due to this and the overwhelming public opposition at the meeting, the Natick Diversion was dropped from consideration as an element in any flood control scheme. There were numerous comments concerning the proposed Natick Diversion. Since it is no longer being considered, comments and questions about it will not be addressed.

COMMENT: 1-1

The impacts to resources as they are expected to be over the entire project life of 100 years should be addressed more fully.

RESPONSE: Estimating or trying to predict the future of an area and its resources is very difficult. The Pawtuxet River basin is presently highly developed. Over the next hundred years growth will occur and the taxing and consum ion of resources will likewise increase. Destruction of natural resources will decrease, though, over time as there will be less resources available for use. The impact of the selected plan on future resources will largely be in the hands of the State and local officials. The plan may give a false sense of security to communities which may in time feel it is "safe" to develop lands in the flood plain; thereby depleting the resource base. The objective of the proposed plan is to help safeguard the natural and manmade resources of the basin both now and over the next hundred years.

COMMENT: 1-2

The impacts of sedimentation should be reevaluated since presently Pawtuxet Cove has to undergo maintenance dredging every eight to ten years.

RESPONSE: Sedimentation in Pawtuxet Cove is caused by two factors, the river and the ocean. Presently, the ocean contributes to the sediments in the cove. The proposed project will not impact on the effect of the ocean. The proposed Big River Reservoir will most likely reduce sedimentation which is carried in the river. Since the basin is small and because of numerous existing small dams on the river, it is felt that the impact of sedimentation will still be minor.

COMMENT: 1-3

By channeling the river near the Warwick Industrial Park, will eight acres of current recreation land (Pawtuxet Reservation) be converted to industrial use?

RESONSE: This land would be adjacent to the industrial park and could possibly be developed in conjunction with the existing use. This decision would have to be made on the local or State level. (See paragraph 4.02)

COMMENT: 1-4

The report has suggested no alternative remedies available if future resource losses prove to be significant.

REPONSE: The comment is directed toward effects of the previously recommended Natick Diversion and the resources of Apponaug Cove and Greenwich Bay. The diversion has been dropped from consideration due to overwhelming public opposition.

COMMENT: 1-5

Plan D has been designated as the EQ (Environmental Quality) Plan. It was our understanding that the EQ Plan was one which enhances by management, conservation, preservation, creation, restoration or improvement, the quality of certain natural and cultural resources and ecological systems in the study area. We question whether or not Plan D fits this criteria.

RESPONSE: At the time when the draft EIS was first released the EQ Plan was Plan D, and was the plan which was the least disruptive to the environment. The plan would improve the quality of certain resources but would degrade others. Whether or not Plan D made net positive contributions to the environmental quality of the area was difficult to determine. The Corps of Engineers ER 1105-2-200 states that in some cases it may be impossible to develop a plan which meets the minimum requirements of an EQ plan. In those cases the plan that is the least environmentally damaging will be designated as the EQ plan. Since the draft EIS was filed, a number of other alternative plans were developed. The current EQ plan is Alternative I and is described in Section 6 of the EIS.

COMMENT: 1-6

Plan D should evaluate the possibility of eliminating channel relocation and study locating a dike on the southern bank of the meander in the river.

RESPONSE: During the planning stages this was studied and it was determined that the costs to do it would be more than the channelization work. Also, the hydraulics of the river would be affected slightly by following the existing river course. The river flow would become slightly more sluggish and would not flow as smoothly and efficiently.

COMMENT: 2-1

Sludge deposits from treatment plants which are currently stored along the river could pose a problem to the water quality of the Pawtuxet as a result of surface runoff and not just during flooding events.

RESONPSE: This is true and is most probably occuring at present.

COMMENT: 2-2

The impacts of sedimentation due to the project should be reevaluated since dredging is required every 8 to 10 years in Pawtuxet Cove.

RESPONSE: See Response 1-2.

COMMENT: 2-3

We believe that the straightening of the river near the Pawtuxet Reservation is a major environmental impact and should be so stated in the final EIS.

RESPONSE: It is noted the "straightening and filling of the River near the Warwick Industrial Park will have long term impacts to both aquatic and terrestrial habitat." (See paragraph 5.07 under the section dealing with Probable Adverse Environmental Impacts that Cannot be Avoided.)

COMMENT: 2-4

The project should be coordinated with the Coastal Resources Management Council of Rhode Island since the State did not have an approved CZM plan.

RESPONSE: At the time of the submittal of the draft EIS the selected plan included the Natick Diversion, which would have discharged flood waters into Apponaug Cove and Greenwich Bay. This diversion had the potential to do environmental damage to both commercial and recreational interests. This plan has been dropped from consideration. It is not anticipated that the final selected plan will adversely effect the coastal environment and its resources.

COMMENT: 3-1

Why wasn't relocation of industry to other areas considered?

RESPONSE: It was investigated but costs to do that would exceed the cost of the protective works.

COMMENT: 3-2

Section 4.08 shows figures for land valuation and job expansion potential. Are they good estimates? Were they used to compute benefit cost calculations?

RESPONSE: If a dike system were built to prevent flooding at the Warwick Industrial Park, more land that is currently undesirable because of flooding would become available for development. Growth trends indicated that the protected land would increase in value and would receive pressure to be developed. In computing the benefit-cost ratio, land enhancement benefits were taken for this land and figured into the B-C ratio. (A detailed breakdown of the benefit-cost computations can be found in the Technical Appendices to the Main Report).

COMMENT: 3-3

We question whether adequate attention has been given to construction impacts (sediment loads, spilled fuel, high pH runoff from concrete).

RESPONSE: Construction activities will impact the project in varying degrees. These impacts are discussed in Sections 4.10 - 4.17 and 4.29 - 4.30. Contractors are required to take precautions to prevent accidents on the job site. A safety plan must be submitted to the Corps of Engineers before construction work can begin. The plan describes in detail how accidents will be prevented. Also, in areas where erosion could occur due to land runoff, hay bales and sediment retention basins should be utilized to prevent contamination of the river and other natural resources.

COMMENT: 3-4

"We strongly believe the alternative plans of No-Action and Regulatory Measures should be given further consideration."

RESPONSE: The No-Action plan and Regulatory Measures were carried through the entire planning process. Regulatory Measures considered were the National Flood Insurance Program (NFIP), flood plain regulations, land use programs and others (See Table VI-1). These measures are meant to supplement the Corrective Measures of reservoirs, walls and dikes, hurricane barriers, floodproofing, etc. By themselves, the No-Action and Regulatory Measures would not provide significant flood protection to existing homes and industry along the river.

COMMENT: 4-1

Several major structural and non-structural obstructions within the riverbed should be removed to restore the natural capacity of the river. They include: dumped rubble, obsolete foundations to old dams and bridges, sediments behind the Broad Street Dam and the dam itself, and a 20 ft. high concrete earth-filled wall jutting across the spillway of the Broad Street Dam.

RESPONSE: Removal of these obstructions would not make a significant contribution to flood control on the lower Pawtuxet River. To begin with, the removal of such objects would only have a minor effect on riverine flooding and no effect on tidal flooding in the lower basin. Secondly, localized obstructions generally have a localized effect. Therefore, effective channel improvements would have to consist of enlarging the channel through deepening and widening. Such improvements would require riprap (stone protection) protection of exposed banks and due to the cost of bridge modifications, the proposal is deemed impractical, particularly since the threat of tidal flooding would still remain.

The removal of the Broad Street Dam would not alleviate the flooding problem. Backwater studies were performed to determine the effects of complete removal of this dam. During a standard project riverine flood the flood stage would be reduced about seven feet at the dam and this reduction would diminish upstream becoming insignificant at Warwick Avenue. Removal of this dam would have the associated impacts of returning the lower Pawtuxet to a tidal estuary with its resulting environmental impact, and normal riverflow velocities would be increased causing possible bank erosion problems if protective measures were not provided. Most importantly, however, removal of the dam would do nothing to protect the lower Pawtuxet against the existing threat from tidal flooding.

COMMENT: 4-2

Scituate and Flat River Reservoirs should be utilized in a greater capacity for flood control storage.

RESPONSE: The idea of providing flood control on the Pawtuxet River by either regulating or adding storage at Scituate has risen many times over the years; however, it is noted that Scituate already provides a high degree of control over its watershed. During many freshets the entire runoff from its watershed is stored in Scituate. Depending on antecedant storage capacity, and during other events where the pool is at or nearly full, surcharge storage in the lake has served to greatly modify and desynchronize the runoff from its watershed. Optimum regulation procedures should be employed at the project to maximize flood control and at the same time not infringe on the water supply yield.

In order to raise the lake at Scituate to increase flood control storage it would be a costly procedure to outfit the dam with new appurtenant flood control facilities, and therefore, is not considered feasible. Due to numerous homes around the lakes perimeter, increasing the water height at Flat River is also not deemed practical.

COMMENT: 4-3

Existing dams along the Pawtuxet should be utilized and designed in a coordinated scheme to provide for flood control.

RESPONSE: Existing dams were investigated and analyzed. It was discovered that these dams had insufficient storage capacity to be an effective element in a flood control system.

COMMENT: 5-1

Consideration should be given to the removal of the large, winged concrete retaining walls at Pawtuxet Village in Warwick which acts as an obstruction to the river.

RESPONSE: See Response 4-1.

COMMENT: 5-2

Consideration should be given to increase the height of the dikes and walls for the local protection project in Warwick.

RESPONSE: The original selected plan included the Natick Diversion which effectively diverted large volumes of flood waters from the Pawtuxet River to Apponaug Cove. Since this plan has been dropped from consideration the dikes and flood walls in Warwick needed to be raised several feet in order to provide for standard project flood (SPF) protection.

COMMENT: 5-3

Consideration should be given to straighten and deepen the Pawtuxet River from the Mall location to its mouth at Pawtuxet Village.

RESPONSE: In order to increase the capacity of the river it would have to be widened significantly and the exposed banks protected with riprap. Bridge modifications would make this proposal impractical. See Comment 4-1.

COMMENT: 6-1

The "probability" that the Federal Government may pay for the additional cost of the flood control element to Big River Reservoir should be made more definite and not require it to be abandoned or be financed by the State.

RESPONSE: Traditionally the Federal Government would pay for the cost of all appurtenant flood control structures. The non-Federal interest would have to provide the costs of all lands, easements, utilities, etc. There is legislation pending which, if passed, would require that the non-Federal interest pay for 25% of the total construction cost. It is not clear, at present, whether or not the State could credit the cost of lands, which are currently owned by them, to their share of the total cost.

COMMENT: 6-2

A joint study should be made by the Army, the Federal Insurance Administration, and the Environmental Protection Agency. It could result in a solution that would be of more immediate benefit, less costly, and less damaging to the environment.

RESPONSE: The Corps of Engineers has been charged by Congress to study the Pawtuxet River Basin to evaluate plans for flood control. Numerous alternative plans were developed offering different degrees of protection. The EPA currently reviews all alternatives and assesses their impacts on the water quality and the environment. Many other Government agencies review the alternatives and comment on the impacts which they feel need to be addressed in more detail. The Federal Insurance Administration is very much interested in plans which advocate wise use of flood plain areas. The process of studying an area, identifying problems, recommending solutions, and implementing measures to solve problems takes a substantial amount of time. Due to regulations, many procedures must be undertaken to satisfy different groups. For all projects, it is the aim of the Corps to develop alternatives which are of the highest benefit to public and also which impact the environment in the least way.

COMMENT: 7-1

The Corps should carefully consider to develop a flood management program which maximizes non-structural solutions.

RESPONSE: Non-structural solutions for flood control were considered during every phase of the planning process. Flood proofing buildings, relocation, flood plain zoning, building codes, recommending limiting future growth in the flood plain were all investigated. A non-structural alternative, Alternative J, was carried through the planning stages even though the flood proofing or relocation of development along the river is not logical, practical, or economically feasible.

COMMENT: 7-2

The Corps should consider channel improvement measures such as clearance of obstructions in the river and restoration of the natural riverbed.

RESPONSE: See Comment 4-1.

COMMENT: 7-3

The Corps should consider strict compliance and enforcement with local flood plain zoning ordinance as defined under the National Flood Insurance Program (NFIP).

RESPONSE: Compliance and enforcement of flood plain zoning is not the Corps of Engineers' charge. However, the Corps strongly advocates that development be strongly controlled by local communities in order to prevent flood damage to home and property.

COMMENT: 7-4

The Corps should consider establishment of local sedimentation and erosion control ordinances.

RESPONSE: The responsibility of establishing local sedimentation and erosion control ordinances would be with the local community and the Soil Conservation Service. The Corps strongly recommends such establishment to prevent the degradation of water quality which may affect the water supply and recreation needs of an area.

COMMENT: 7-5

The Corps should consider improving water storage of Scituate Reservoir and also designing Big River Reservoir for flood surcharge storage.

RESPONSE: See Comment 4-1. The Big River Reservoir is being designed for flood control storage equivalent to six inches of runoff over a drainage area of about 30 square miles. This can be accomplished by increasing the height of the dam about 2.5 feet.

COMMENT: 8-1

Can flood control storage be created at Scituate Reservoir?

RESPONSE: See Comment 4-2

COMMENT: 8-2

We are concerned that there may be a slight increase of flooding in Cranston caused by dikes being built in Warwick.

RESPONSE: The proposed walls and dikes at the Warwick Industrial Park would effectively cut off low lying areas that get flooded during high water. The effect would be that flooding would increase very slightly (several inches), but only in that area of Cranston directly across from the walls and dikes. There would not be an increase in flooding in Cranston upstream from the industrial park. The slight increase in flooding would be eliminated totally by the flood control storage at the Big River Reservoir.

COMMENT: 8-3

We would like to be assured that flood control storage at the Big River Reservoir be completed and all engineering data confirmed by interested R.I. and U.S. Departments before the start of any dike and wall construction in Warwick.

RESPONSE: See Comment 8-2. Big River Reservoir is currently under study by the Corps of Engineers as requested by the State of Rhode Island. The reservoir is planned in conjunction with protective works in Warwick. At present, it cannot be assured that work at Big River be completed before any work is begun at Warwick. However, even if protective works were installed in Warwick the effect in Cranston would only mean a slight increase in flooding of several inches in the area opposite the walls and dikes.

COMMENT: 9-1

The Corps should study the alternative of dredging the river and removing obsolete dams and bridges.

RESPONSE: See Comment 4-1

COMMENT: 9-2

The Corps should recommend removal of obsolete and demolished manmade objects which are encroaching on the river.

RESPONSE: See Comment 4-1.

COMMENT: 9-3

The Corps should recommend remodeling and rehabilitating certain existing dams on the river.

RESPONSE: See Comment 4-3.

COMMENT: 10-1

Why was there not more information given for the Future Action Alternative of utilizing a combined reservoir management system (the Scituate and proposed Big River) for both flood control and water supply?

RESPONSE: At the time that the draft EIS was released, Big River Reservoir was just in the preliminary planning stages. The Corps of Engineers was proposing that if the State constructed the reservoir that flood control should be included over and above the water supply portion of the project. However, in January 1978, the Corps was requested by the Governor of Rhode Island to undertake a feasibility study for both water supply and flood control at Big River. This report, including an Environmental Impact Statement, is scheduled for completion early in 1980. Scituate Reservoir presently provides a high degree of flood control storage for the area. (See Comment 4-2.)

COMMENT: 10-2

Why wasn't an alternative considered utilizing Federal funds under the Corps of Engineers' Small Flood Control Project Regulations for Warwick local protection barriers?

RESPONSE: Prior to studying the entire Pawtuxet River basin, flood prone areas in Warwick were investigated under the Small Projects Regulations (Section 205). At that time the upward limit for a "small project" was one million dollars. At the time that these small projects were being investigated Congress authorized that the Corps should study the entire Pawtuxet River basin for flood control. Instead of doing a Detailed Project Report (DPR) for each small project they were included into a comprehensive plan for the entire basin.

COMMENT: 10-3

The Corps gives estimates on market values for land with and without flood protection and projected increases in number of jobs. Which studies or types of calculations are these derived from?

RESPONSE: These estimates were developed from information supplied by local officials from the planning and assessing departments in Warwick. See Section 4.06.

COMMENT: 10-4

What Federal regulations dictate adherence to the SPF standard of protection?

RESPONSE: The alternative measures considered for urban areas where formulated in accordance with Engineering Circular (EC 1105-2-47) which stipulates that the standard project flood is an appropriate level of protection for high dikes and floodwalls in urban areas. It also states that if the standard project flood protection plan is unjustified or only marginally justified, the level of protection may be reduced to yield a more economically feasible plan by utilizing alternative flood damage reduction measures. However, reductions in the level of protection below the standard project flood are to be avoided whenever possible.

COMMENT: 10-5

The R.I. Department of Health, Division of Air Pollution Control has projected violations of the secondary standard for total suspended particulates (TSP) (60 ug/m^3) by as much as 50ug/m^3 in Cranston and Warwick. The excavation and transportation of earth from the dikes qualifies as a source of TSP. What is a reasonable estimate of the source strength? What would the contribution to TSP levels in Warwick and Cranston be during typical weather conditions? On those days characterized as transport days, what contribution will the source be to TSP levels in the Providence business district?

RESPONSE: Construction activities will no doubt cause a temporary increase in the levels of TSP. Precautions to reduce the dust will be utilized during the time of construction. The data that is sought is of a very advanced nature that would not be investigated during this stage of project analysis and design.

PAWCATUCK RIVER AND
NARRAGANSETT BAY DRAINAGE BASINS

INTERIM REPORT
PAWTUXET RIVER WATERSHED
RHODE ISLAND

APPENDICES TO

MAIN REPORT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

APPENDIX 1

PROBLEM IDENTIFICATION

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FIGURE

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STUDY AUTHORITIES

This report is submitted in partial compliance with seven Congressional resolutions that authorized the Pawcatuck River and Narragansett Bay drainage basins (PNB) study. The following resolutions pertain to the Pawtuxet River Basin:

Resolution adopted on 29 March 1968 by the Committee on Public Works of the United States Senate:

> "That the Board of Engineers for River and Harbors, created under Section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby requested to review the report on Land and Water Resources of the New England - New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining, in light of the heavy damages suffered during the storm of March 1968, in southern New England, the advisability of improvements, particularly in the Pawcatuck River Basin, Rhode Island, and the Narragansett Bay Drainage Basin, Massachusetts and Rhode Island, in the interest of flood control, navigation, water supply, water quality control, recreation, low-flow augmentation, and other allied water uses."

Resolution adopted on 10 July 1968 by the Committee on Public Works of the House of Representatives:

> "That the Board of Engineers for Rivers and Harbors is hereby requested to review the reports on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining, in light of the heavy damages suffered during the storm of March 1968, in southern New England, the advisability of improvements, particularly in the Pawcatuck River Basin, Rhode Island, and in the Narragansett Bay Drainage Basin, Massachusetts and Rhode Island, in the interest of flood control, navigation, water supply, water quality control, recreation, low-flow augmentation, and other allied water uses."

Resolution adopted on 2 February 1970 by the Committee on Public Works of the United States Senate:

> "That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby requested to review the report on Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, and other pertinent reports, with a view to determining whether any improvements for flood control and other water resources purposes are advisable at this time, particularly along the Pawtuxet River, Pocasset River, and Meshanticut Brook, at and in the vicinity of Cranston, Rhode Island."

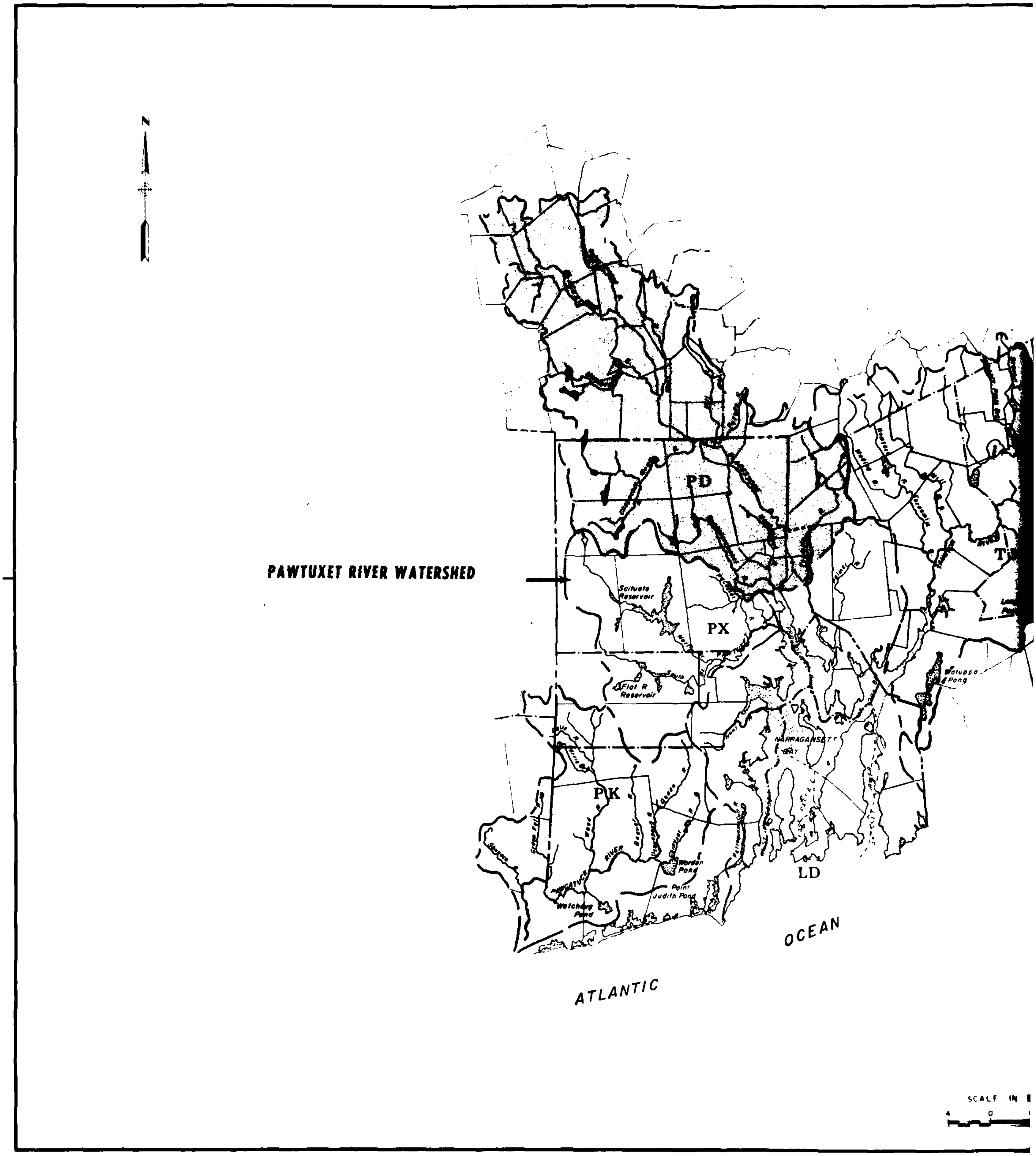
SCOPE OF THE STUDY

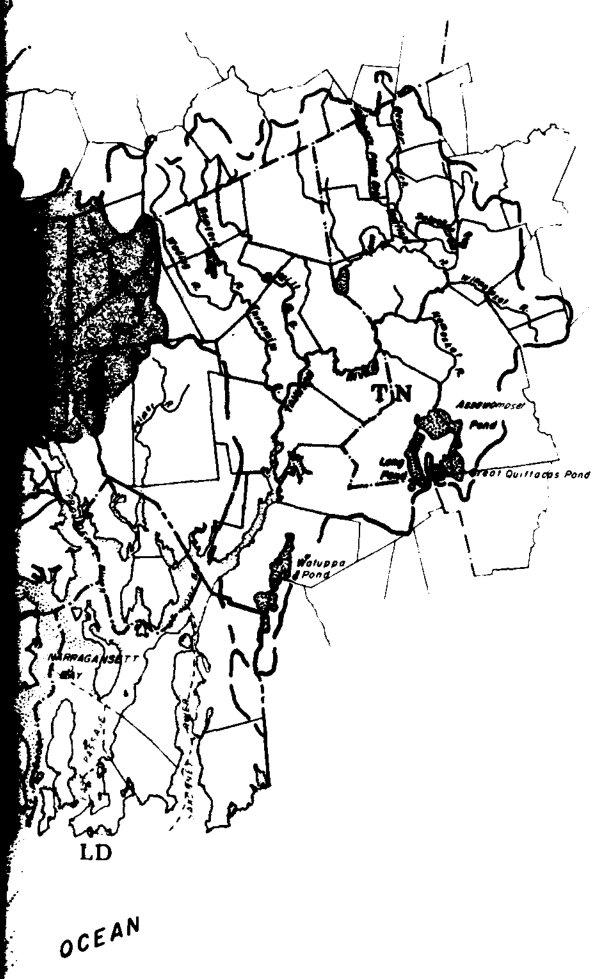
This report presents the results of a study of the water resource problems in the Pawtuxet River Basin, one of the five major watersheds in the Pawcatuck River and Narragansett Bay Drainage Basins (PNB) Study, for the purpose of determining the advisability of improvements in the interest of flood control and allied purposes. A map showing the relationship of the Pawtuxet River and the PNB study area follows on Plate 1-1.

PRIOR STUDIES AND REPORTS

EARLY RHODE ISLAND WATER SUPPLY REPORTS

Reports prepared in January 1928 and September 1936 by the Rhode Island State water supply and planning agencies provide information concerning the watershed record flood of February 1886. Additional hydrologic information has been compiled by the city of Providence, which has diverted water from the Pawtuxet River into its public supply since 1870. Detailed water supply studies were also completed by the city of Providence as the result of the 1915 Water Act of Rhode Island, which authorized the development and 1926 completion of Scituate Reservoir on the North Nashua Branch in Scituate.


N
PAWTUXET RIVER WATERSHED
PD
PX
PK
LD
T
Scituate Reservoir
Flat R. Reservoir
NARRAGANSETT BAY
Worden Pond
Point Judith Pond
Watchaug Pond
Watuppa Pond
ATLANTIC
OCEAN
SCALE IN



LEGEND

		COMMUNITY BOUNDARY
		COUNTY BOUNDARY
		STATE LINE
	PD	PROVIDENCE RIVER GROUP
→	PX	PAWTUXET RIVER BASIN
	TN	TAUNTON RIVER BASIN
	PK	PAWCATUCK RIVER BASIN
	LD	LOCAL DRAINAGE

SCALE IN MILES

4 0 4 8

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

PNB STUDY AREA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 1-1

FLOOD CONTROL SURVEY REPORT

In response to Section 5 of the 1937 Flood Control Act, a report prepared in October 1939 by the former Providence District, Corps of Engineers recommended adoption of a flood control plan for the Pawtuxet River watershed. The plan entailed local protection works at Clyde (along the North branch in West Warwick) and a gated diversion dam near Pontiac (along the main river in Warwick) that would divert floodwaters from the main river southward through a diversion channel that would discharge at Apponaug Cove, at the head of Greenwich Bay in Warwick. Both projects were authorized by the 1941 Flood Control Act, but authorization expired in 1951 as local participation (lands, easements, right-of-ways, cost sharing in 25 percent of the first cost of the Pontiac Diversion not to exceed $347,500, and operation and maintenance of the project following completion) was not forthcoming.

NENYIAC REPORT

A report by the New England-New York Inter-Agency Committee (NENYIAC) was completed in March 1955. It contained an inventory of resources and addressed streamflow regulation, water supply, water quality, flood control, hydroelectric power, navigation, shore erosion, fish and wildlife, recreation, historic sites, land management, mineral production, and insect control. The report indicated that benefits could be realized from streamflow regulation, pollution control and flood control measures in the Pawtuxet watershed, but no projects were recommended for these or other study elements. Chapter XVII of Part Two, "Narragansett Bay Drainage Basins," discusses the resources of the Pawtuxet, Blackstone and Taunton watersheds and local drainage into Narragansett Bay and the Sakonnet River.

NAVIGATION SURVEY REPORT

In response to a resolution by the House of Representatives Committee on Public Works, a report published in June 1961 by the New England Division, Corps of Engineers recommended a small boat harbor improvement at Pawtuxet Cove, a tidewater indentation at the mouth of the river. The project was authorized by the 1962 River and Harbor Act and was completed in 1966. It entailed dredging an entrance channel 6 feet deep and 100 feet wide, and a turning basin at the northern end; dredging an anchorage 6 feet deep over a 14 acre area at the south side of the entrance channel; and constructing a 2,200-foot long sheltering dike at the east side of the anchorage.

NARRAGANSETT BAY AREA HURRICANE SURVEY REPORTS

The Public Law 84-71 study authority, was adopted by the New England Division, Corps of Engineers, after the damaging hurricanes of 31 August and 11 September 1954, an interim report was completed in August 1957. This led to a series of reports and to the 1958 authorization and 1961-66 construction of the Fox Point Barrier across the upper reach of the Providence River at Providence. A plan for hurricane tidal flood protection for the Narragansett Bay area, known as the Lower Bay Barriers, was completed in January 1965 by the New England Division. The report recommended the provision of rockfill barriers (top elevation 25 feet above mean sea level) across the East and West passages to Narragansett Bay and across the upper passage of the Sakonnet River, subject to local agreement for participation in the project. Ungated navigation openings would be provided at each passage and 80 sluice gates would normally remain open to allow additional tidal interchange. The barriers would reduce the wave action level of 18 feet at Pawtuxet Cove that accompanied the record hurricane flood of 21 September 1938 (frequency slightly less than once in one hundred years), to approximately 10.6 feet, and would reduce the 1938 tide (stillwater) level of 15.3 feet to approximately 7.8 feet.

A majority of the persons commenting at the 1956 public meeting on the Fox Point Barrier project expressed general approval of the lower Narragansett Bay protection concept. Support by Massachusetts interests continued strong during the course of the Narragansett Bay Study. However, support by Rhode Island citizens waned and opposition was expressed concerning various biological, aesthetic, tidal interchange, water quality, salinity and navigation aspects of the Lower Bay Barriers plan. In view of this lack of support, the Secretary of the Army's report to the Congress recommended that no project be authorized for the lower Narragansett Bay area until Rhode Island citizens expressed approval of the project.

RHODE ISLAND WATER SUPPLY REPORT

A report to the Rhode Island Water Resources Board, prepared in June 1967 by Metcalf & Eddy, Inc., updated 1952-1957 consultant reports to the Board to reflect the drought conditions of the early 1960's and the attendant water supply problems. The report proposed a phased development program to meet increased demands expected in 1990 and 2020. The report proposed construction (about 1980) of a reservoir on the Big River just upstream from the existing Flat River Reservoir (industrial water supply) to produce an initial 29 MGD of water supply for the Providence metropolitan

service area. Also proposed were flood skimming of the Flat River (about 1995) and transfer to Big River Reservoir, plus development of facilities after 2005 that would divert flood flows from the tributaries of the Thames and Pawcatuck River Basins, located to the west, to augment the yields of Big River Reservoir. In conjunction with these studies, the Water Resources Board during 1965-66 acquired 8,270 acres for the Big River Reservoir project. The initial phase of environmental assessment and preliminary engineering and design on the Big River project is in progress by Water Resources Board consultants.

NEWS STUDY FEASIBILITY REPORT

Under the authority of the 1965 Flood Control Act the Corps of Engineers conducted a regionwide assessment of water supply problems of the metropolitan areas between Maine and Virginia as part of the Northeastern United States Water Supply Study. A draft report was prepared by the New England Division in November 1969 concerning long-range water supply needs in Rhode Island and most of Massachusetts. The surface water projects proposed for the Pawtuxet watershed area are the same as those recommended in the 1967 Metcalf & Eddy report to the Rhode Island Water Resources Coordinating Board. No ground water projects were proposed for the Pawtuxet watershed area by the U.S. Geological Survey, who analyzed all existing ground water reports as their contribution to the study.

FLOOD CONTROL RECONNAISSANCE REPORT

In initial response to the PNB study request, a reconnaissance report was completed in December 1971 by the New England Division, Corps of Engineers, which presented the findings from a preliminary study of the flood problems in the Pawtuxet River watershed. The report indicated that the potential flood problems which result from the existing pattern of growth within the flood plains, are of such magnitude that a flood management program composed of nonstructural and structural measures should be encouraged. The preliminary investigation indicated that detailed studies were warranted to evaluate a management program of regulatory measures (namely flood proofing) and corrective measures such as a diversion project, local protection, modification of Scituate Reservoir, and future floodwater storage at the State proposed Big River Reservoir project.

NAR REPORT

Authorized by the 1965 Flood Control Act, the North Atlantic Regional Water Resources (NAR) Study was one of 20 regional studies

conducted throughout the United States under Level A guidelines established by North Atlantic Division, Corps of Engineers, the report encompassed all river basins draining into the Atlantic Ocean from Maine to Virginia and all New York and Vermont areas draining into the St. Lawrence River from St. Regis, New York eastward. The objective was to establish a broad master plan or framework as a basis for regional water and related land resources management. Fifteen water resource needs in each of the 21 subregions of the NAR study area were projected through the year 2020 in accordance with several planning objectives: environmental quality, national efficiency (or income), regional development or mixed objectives. A basic finding for the entire study area was that NAR water resources cannot support further continuation of the traditional pattern of development and consumption. Research and study and management of water, land and environmental resources are needed to reduce the needs for excessive monetary and natural resource investments.

The report indicated that the PNB area will need help in eliminating its unemployment. Its water resource management program should be oriented toward increasing regional development, but with some environmental quality constraints. Key long-term (2020) needs for the PNB area are water quality management and improvement to meet State standards, availability of power plant cooling water (mostly saltwater sites), water supply withdrawal and importation measures (with future shift expected by many industries from self-supplied to publicly supplied systems), flood damage reduction measures as land becomes scarce, commercial navigation improvements, shore erosion protection for selected sites, and increased opportunities for water-oriented recreation, fish and wildlife recreation, and recreational boating.

BROWN UNIVERSITY WATER QUALITY REPORT

A Brown University report was published in August 1972 based on a 1971 summer student group study of the Pawtuxet main river and the North and South Branches. This report stated that water quality, already poor, had deteriorated by one or two water use classifications in most reaches since the Rhode Island Department of Health Analysis of 1966. The report also indicated that existing water quality management is ineffective and a strong regional management agency is needed, one that can collect monetary charges on effluents. Also needed is the formation of a water quality monitoring consortium, consisting of industries and sewage treatment plants, for year-round monitoring of the river.

CRANSTON FLOOD HAZARD ANALYSIS REPORT

At the request of the city of Cranston and Rhode Island Statewide Planning Program, officials, a flood hazard analysis report on the Pocasset River and Meshanticut Brook within Cranston was published in September 1973 by the Soil Conservation Service. An addendum to this report was published in December 1974. The report contains flood maps, high water profiles and typical valley cross-sections that provide a guide for the development of local regulations and other flood management measures for minimizing flood damages. Information was compiled for 10-year, 50-year, 100-year and 500-year frequency floods. The flood maps show only the 50-year and 500-year flood limits. The 100-year flood limits are essentially the same as the 50-year flood limits.

FLOOD CONTROL PROJECT ENVIRONMENTAL REPORTS

At the request of the New England Division, Parsons, Brinckerhoff, Quade and Douglas, Inc. prepared an environmental report in February 1975 (with minor May 1975 revisions). It concerned measures to reduce flood damages in the Pawtuxet River watershed were under consideration by the PNB study team. It also discussed the environmental setting without the proposed flood control measures, the probable impacts of the proposed actions, and alternatives to the proposed actions. The report findings were summarized in the information pamphlet prepared for the mid-stage public meetings held by the New England Division at Warwick and Cranston in May 1975.

An environmental report which discusses marine life at Apponaug Cove and the Greenwich Bay area was prepared in September 1975 by Dr. James Hoff and Dr. Sanford A. Moss, Biology Department, Southeastern Massachusetts University, at the request of the New England Division. Their survey, mostly of Greenwich Bay, consisted of water quality analyses, fin fish estimates, and sampling and identification of soft shell clams, other benthic life and plankton at selected sampling stations in Apponaug Cove, Greenwich Bay, Providence River and Gorton Pond.

SOUTHEASTERN NEW ENGLAND (SENE) REPORT

As part of the program established by the 1965 Water Resources Planning Act so that multi-purpose, coordinated plans would be developed for each subregion or major river basin in the Nation, the Water Resources Council authorized a comprehensive level B study of the coastal basins of eastern Massachusetts, Rhode Island and the southeastern corner of Connecticut. Under the direction of the New England River Basins Commission, a Federal-State study team

evaluated existing, 1990 and 2020 needs in the SENE area which includes all of the PNB area. These are principally water supply, water quality, recreation, marine management, flooding and erosion, minerals extraction, and the siting of electrical power and petroleum facilities. The report to the Water Resources Council, submitted in March 1976, indicated that continuing urban growth in the SENE area can be accommodated but should be guided to protect fragile resources and make development more efficient.

Key recommendations for meeting 1990 needs in the Pawtuxet River Basin were: petition the General Assembly to approve construction of Big River Reservoir; expand Cranston and Warwick secondary treatment plants; consider construction of a complete secondary treatment plant at Coventry or expand the existing secondary treatment plant at West Warwick; acquire key wetlands and flood plains; and consider non-structural flood plain management solutions wherever possible, under the authority of Section 73 of the Water Resources Development Act of 1974. The SENE Study efforts were closely coordinated with those of the PNB study.

The SENE study recognized that specific project proposals to resolve the major flood problems in the lower basin were being evaluated by the PNB study team. Therefore, the recommendations of the SENE study focused on regulatory, soil conservation and forestry measures that all basin municipalities should adopt to reduce flood plain encroachment, erosion and nonpoint source pollution.

MATHEMATICAL MODEL ANALYSIS

At the request of the New England Division, the Raytheon Company, Portsmouth, Rhode Island, was asked to forecast the dispersion of key water quality parameters in Apponaug Cove and Greenwich Bay. The company was also requested to forecast the biological impact on biota in both saltwater areas, as the result of proposed freshwater diversions from the Pawtuxet River to Apponaug Cove during flood events. The mechanism used for these forecasts entailed modification of an existing Narragansett Bay circulation model and effluent dispersion model. Their pertinent findings are discussed in Appendix 4.

FLOOD INSURANCE STUDIES

Under the authority of the National Flood Insurance Act of 1968, Flood Insurance Study Reports have been prepared for the Federal Insurance Administration, Department of Housing and Urban Development for the communities of Cranston, East Greenwich, West Warwick, Coventry, Providence and Warwick, which are operating

under the regular program. The communities of Exeter, Foster, Glocester, Johnston, Scituate and West Greenwich have requested flood insurance studies and are presently eligible for flood insurance under the emergency program until specific flood zones and actuarial rates are determined and flood plain zoning is enacted.

EPA WATER QUALITY STUDY

A one-year water quality sampling and analyses program for the Pawtuxet River was initiated in September 1975 by the Environmental Protection Agency (EPA) Laboratory in Needham, Massachusetts and the National Marine Water Quality Laboratory in West Kingston, Rhode Island. The program entails collection of water samples from the Pawtuxet River at three sampling stations upstream of the proposed Natick Diversion site in the vicinity of Natick Pond and another sampling station near the river mouth during 20 proposed sampling periods. The program includes bacteriological analyses for total and fecal coliforms and physical-chemical analyses for nonfilterable residue, biochemical oxygen demand (BOD) ultimate and various heavy metals. Preliminary results are discussed in Section 4 under the heading "Natick Diversion."

Flood plain information studies of the selected streams in Cranston, Warwick and West Warwick have been completed by the New England Division, Corps of Engineers. A similar study, a flood hazard analysis of the Pocasset River in Johnston, has been completed by the Soil Conservation Service at West Warwick.

PNB WATER SUPPLY STUDY

A study of water supply alternatives for the Pawcatuck River and Narragansett Bay (PNB) drainage basins was completed in January 1979 by Metcalf & Eddy, Inc. for the New England Division, Army Corps of Engineers. The report proposed alternative water supply plans to serve the PNB region, including surface water, ground water, and combinations. The recommended plan included development of the Big River Reservoir to help meet future demands of the Providence area.

FLOOD PROBLEMS

INTRODUCTION

Historical records of floods in the Pawtuxet River Basin date to the early 1800's. Throughout this period numerous flood producing

storms have been experienced but none produced high monetary losses. Until the recent 15 year time period the basin has maintained its rural characteristics with many of its lands sustaining agricultural needs. Being within a few miles of Providence, in close proximity to the seashore and well serviced by a complete interstate highway system, the area has become captive to the demands imposed by urbanization. The exodus of people from the city is exerting pressure on the basin communities as more of the vacant land is developed. Under a continuing trend of land use changes, the basin is more susceptible to greater flood losses.

This increase in urbanization has resulted in increased use of the flood plains. They are the most economical areas to develop - other land available at nominal cost is rather scarce. Also, compounding the issue, is the highway system because it provides easy access to the flood plains, making them vulnerable to land speculators.

During the drought years of the early 1960's, numerous commercial and industrial complexes and residential homes were constructed within the main stem flood plain of the Pawtuxet River and its major tributaries. During those years, because water levels in the upstream reservoirs (particularly Scituate Reservoir) were below normal, little fear of potential flooding existed. Structures were constructed with first floor slab elevation only slightly above existing ground. Flood proofing was not even a consideration. Since the area had been previously spared from serious damaging floods, the land development attitude strongly persisted until the March 1968 flood. With the occurrence of this high probability event, flood damages which would normally have been insignificant became alarmingly critical.

The antecedent conditions in 1968 were conducive to causing moderate flood losses. Due to the modifying effect of Scituate Reservoir, still about five feet lower than normal due to the drought and capable of storing flood flows flood losses along the main stem were minimized. Through the intervening years growth trends continued unabated to such an extent that some of the flood plains became saturated with new developments. In this period existing zoning regulations, imposed by the local government, permitted slab elevations equivalent to but not less than a 50-year flood frequency. With the advent of the National Flood Insurance Act (PL 90-448) new criteria was applied on a very gradual basis, a pace so slow that much of the vacant land had already been occupied.

At the same time lands adjacent to the flood plains, particularly those in close proximity to highway interchanges, were intensively

developed. Vegetated areas have been replaced with paved parking lots, streets, highways and other developments causing a degree of topographic changes. A large percentage of former natural storage areas, once available to retain excessive runoff, has been lost.

EXISTING CONDITIONS

The Pawtuxet River watershed lies entirely within west-central Rhode Island and encompasses an area of 230 square miles (approximately 147,000 acres). Its headwaters originate in the hilly uplands near the Connecticut State line. The basin is triangular in shape and the tributary streams converge on the short main stem of the river, which discharges at the apex of the triangle at Pawtuxet Cove on Narragansett Bay. The maximum width of the basin in a north-south direction is 23 miles and its length is 18 miles. River mileage from Ponaganset Reservoir (at the head of the North Branch) to Pawtuxet Cove is approximately 32 miles.

Most of the larger streams are highly developed by former industrial waterpower installations and conservation storage. Excluding farm impoundments over 150 dams plus natural lakes and ponds provide about 11 square miles of water surface area. Located near the southwestern end of the Providence metropolitan area, the eastern third of the watershed is a highly urbanized industrial-commercial area. A narrow transitional zone immediately to the west is rapidly changing to a suburban area. The western half of the western is largely rural, with small villages located mostly along the east-west highways. The watershed is bounded by the Blackstone and Woonasquatucket River Basins on the north, the Thames River Basin on the west, and the Pawcatuck River Basin on the southwest and Narragansett Bay local drainage on the southeast. A map of the Pawtuxet River Basin is shown in Plate 1-2.

The main stem of the Pawtuxet River begins in West Warwick at the confluence of the North and South branches and terminates at the Pawtuxet Dam in Pawtuxet Cove. In this reach approximately 2000 buildings, including homes and commercial establishments would be flooded to various levels from a flood of a standard project flood designation (maximum flood caused by conditions characteristic of the area). For purposes of damage evaluation, the river was subdivided into 16 zones as shown later in this report on Plate 1-3. Damages are most significant along the main stem in zones 4, 5, 7 and 8. Damages from overland flooding of the tributaries are almost non-existent in zones 1, 2, 3, 4A and 7A from even a standard project flood storm. In these 5 zones only several small shops or residences in each area would be flooded. Ground water flooding or backing up of small tributaries due to inadequate

channel openings have not been considered as their potential solutions cannot be accomplished under existing Corps authorities.

Damage potentials for each of the eleven damage areas are discussed in the following paragraphs:

PAWTUXET RIVER TRIBUTARIES

South Branch - Zone 2A

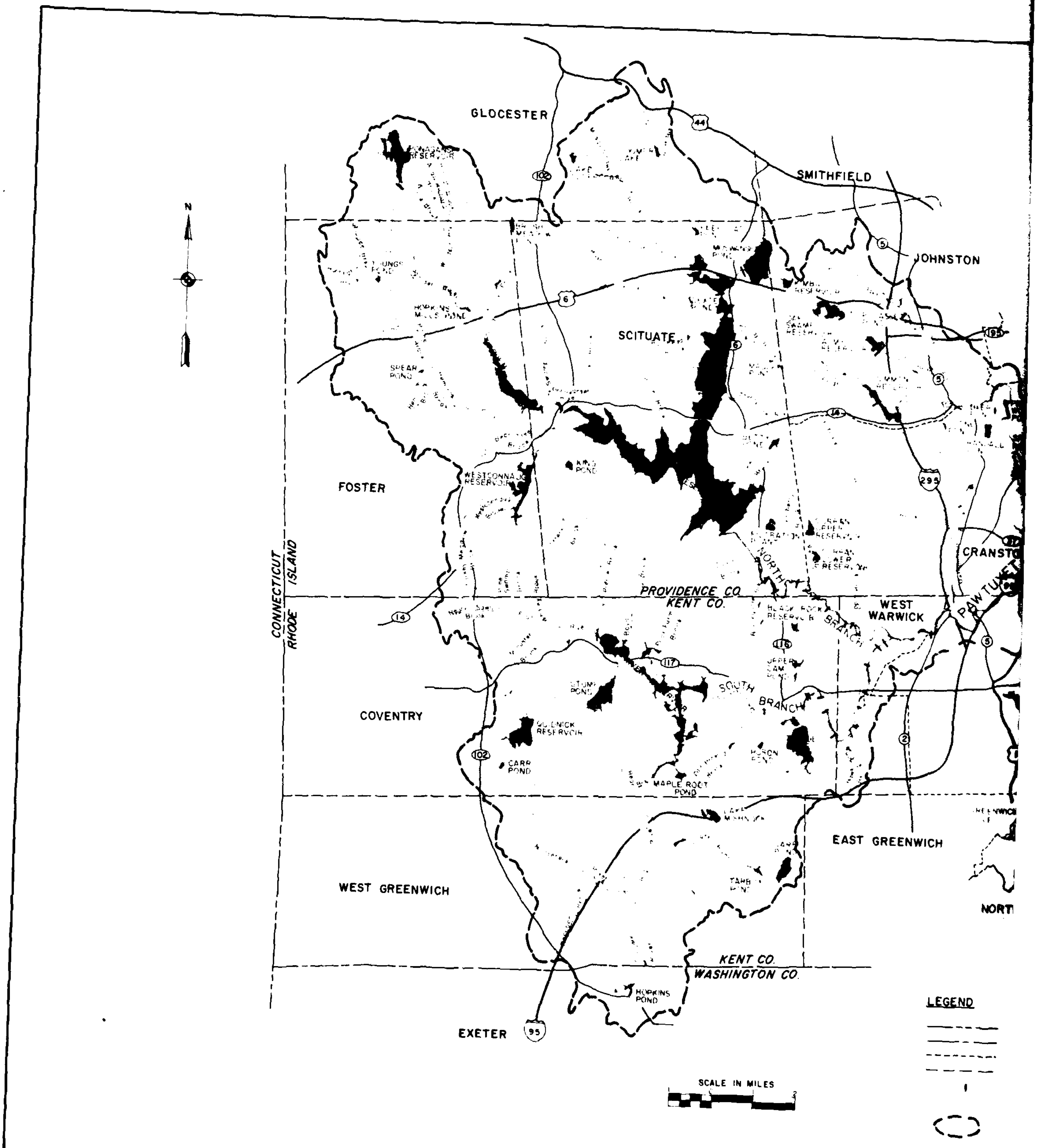
This zone, running from the Flat River Reservoir downstream to the confluence with the North branch has several areas along the main stem South branch that could receive significant losses at major storm events. In addition, the American Hoescht Corporation has several structures that could experience losses at an intermediate flood event. The Bradford Soap Works building, Ace Dying Co., Natco Products building and the Nidark structure are the remaining areas of concern should a major flood event occur. Residential structures are relatively safe from overland flooding. Local concerns have expressed interest in Baker Street Brook. This area suffers from inadequately sized culvert openings and the associated flooding is classified as a local drainage problem.

Average annual damages in this reach are overall relatively minor.

North Branch - Zone 1A

Annual damages in the reach of river from the Gainer Memorial Dam (Scituate Reservoir) to the confluence with the South Branch would also be classified as minor. Several areas are prone to damages from an intermediate range flood (1% chance of occurrence). Some flood reduction is afforded these areas by the Scituate Reservoir due to just surcharge storage above the maximum water supply pool. If the flood occurs at a time when the water supply pool is at a lower level, even higher degrees of protection are provided with correspondingly less likelihood of damages. The areas that could be impacted are as follows: a group of cottage type homes just downstream of Colvin Brook, Valley Lace Co., Falvey Liney Co. (all located in Scituate), Arkwright Co. building, a group of small commercial shops in Harris, Hamilton Auslander Co., and a commercial complex - bus storage yard in Clyde, all the latter located in West Warwick.

Local flooding of tributaries such as Lippett and Phenix Brooks does occur but are due to inadequately sized culvert openings.



GLOCESTER
SMITHFIELD
JOHNSTON
SCITUATE
FOSTER
CRANSTO
PAWTUXET
WEST WARWICK
COVENTRY
EAST GREENWICH
WEST GREENWICH
EXETER
NORTH BRANCH
SOUTH BRANCH
PROVIDENCE CO.
KENT CO.
WASHINGTON CO.
CONNECTICUT
RHODE ISLAND
WESTCONNAUG RESERVOIR
SPEAR POND
HOPKINS MILLS POND
KING POND
QUIDNICK RESERVOIR
CARR POND
MAPLE ROOT POND
HOPKINS POND
TARR POND
STUMP POND
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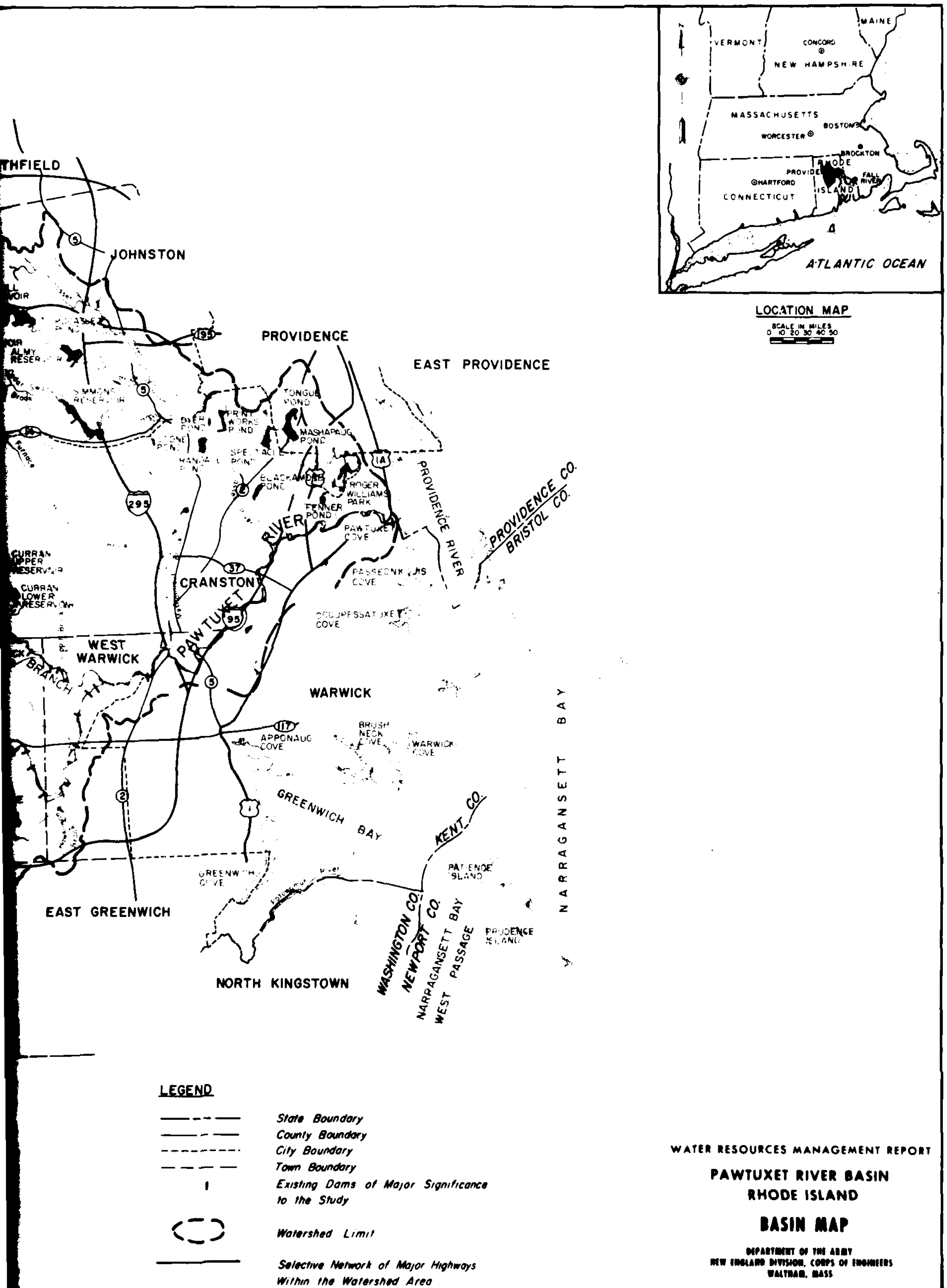
LEGEND
SCALE IN MILES



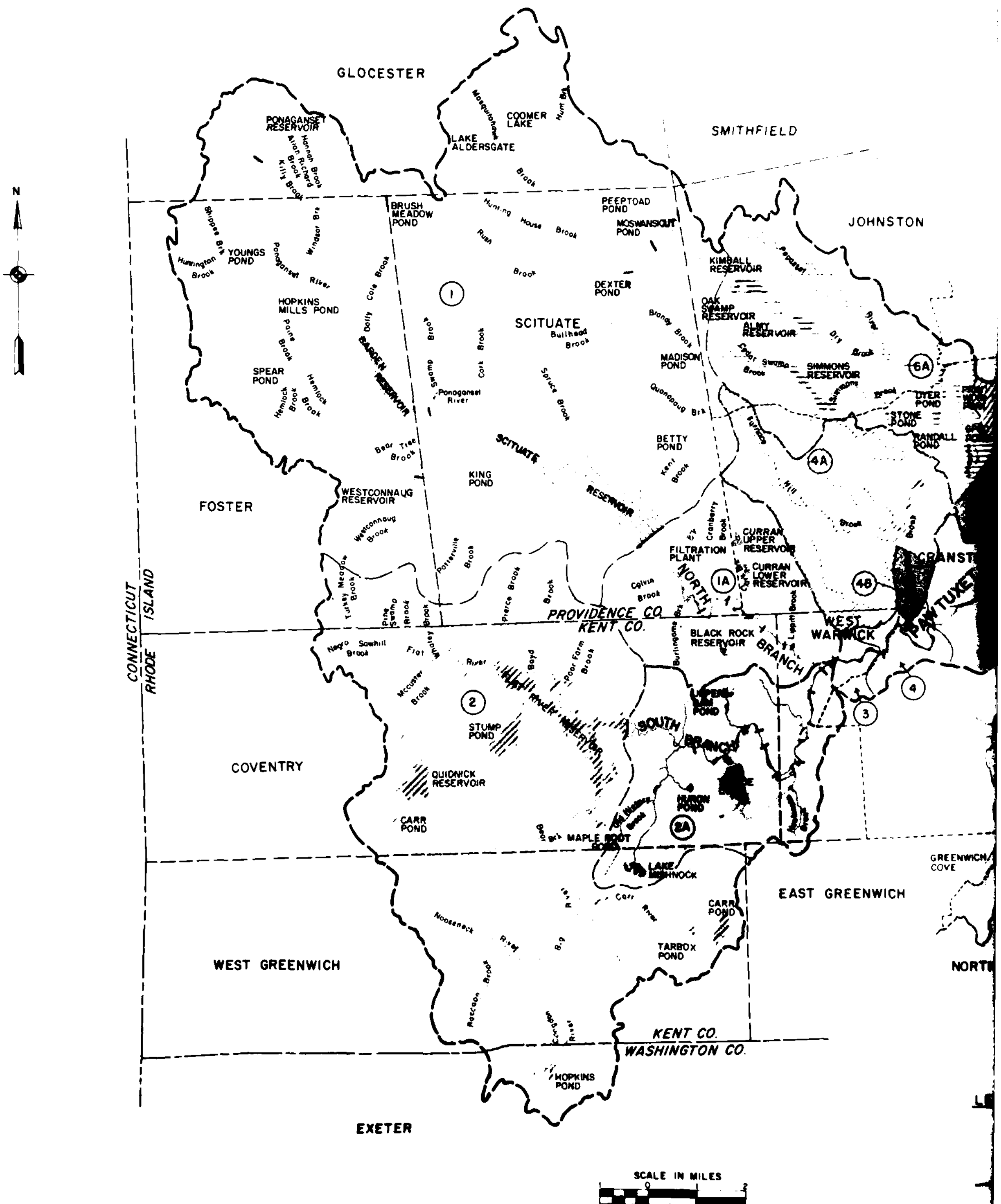
WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

BASIN MAP

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 1-2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EAST GREENWICH
EXETER
WEST WARWICK
PONAGANSET RESERVOIR
COOMER LAKE
LAKE ALDERSGATE
PEEPTOAD POND
MOSWANSICUT POND
BRUSH MEADOW POND
YOUNGS POND
HOPKINS MILLS POND
SPEAR POND
DEXTER POND
KIMBALL RESERVOIR
OAK SWAMP RESERVOIR
ALMY RESERVOIR
SIMMONS RESERVOIR
MADISON POND
BETTY POND
KING POND
WESTCONNAUG RESERVOIR
FILTRATION PLANT
CURRAN UPPER RESERVOIR
CURRAN LOWER RESERVOIR
DYER POND
STONE POND
RANDALL POND
BLACK ROCK RESERVOIR
STUMP POND
QUIDNICK RESERVOIR
CARR POND
HURON POND
MAPLE ROOT POND
LAKE MISHNOCK
TARBOX POND
HOPKINS POND
GREENWICH COVE
PROVIDENCE CO.
KENT CO.
WASHINGTON CO.
CONNECTICUT
RHODE ISLAND
SCALE IN MILES
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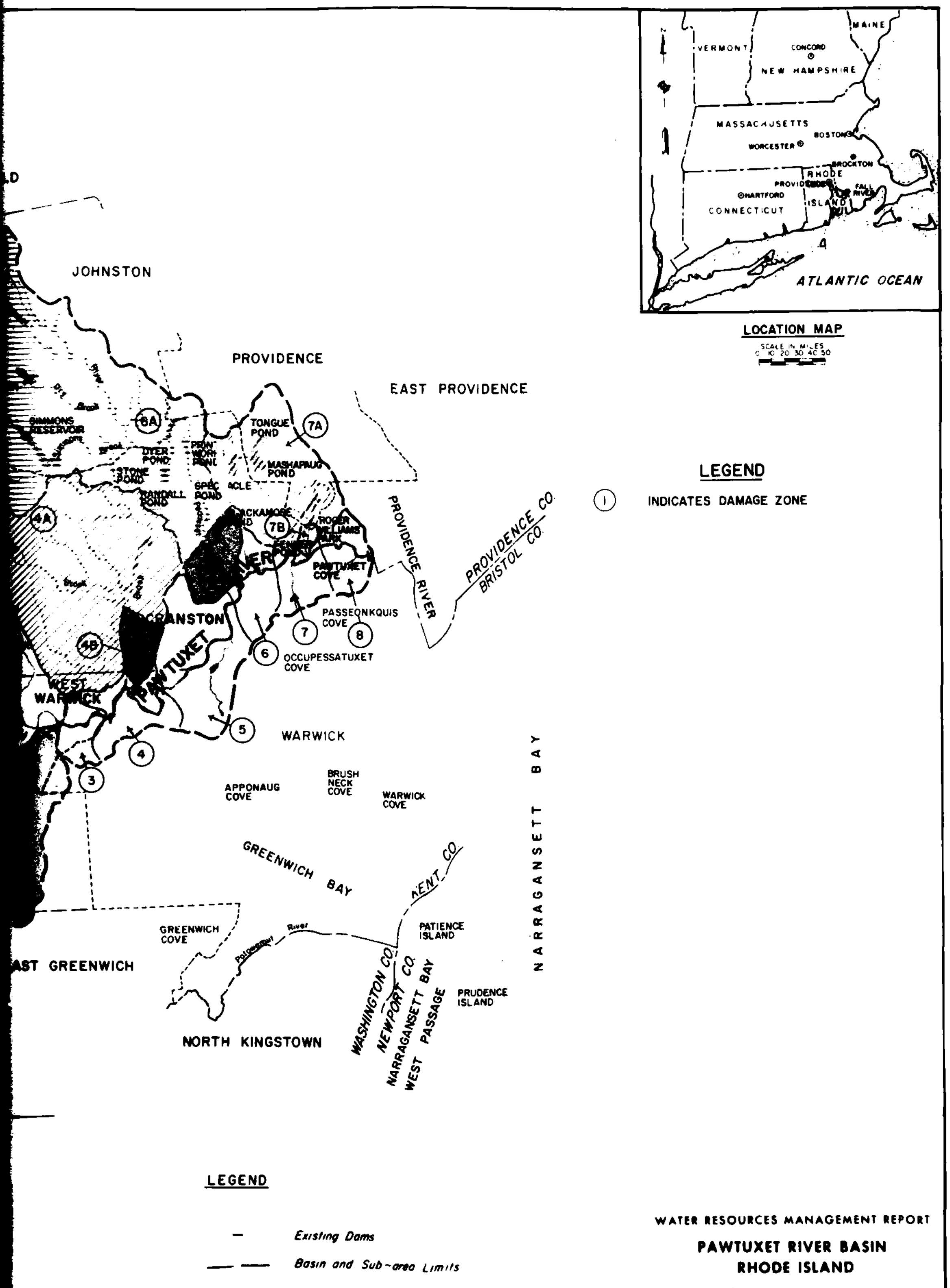
1A
2
2A
3
4
4A
4B
6A



WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

DAMAGE ZONES

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 1-3

Meshanticut Brook - Zone 4B

This reach runs from the I-295 bridge crossing south of Wilbur Avenue down to the confluence with the Pawtuxet River just below the West Warwick Sewage Treatment Plant. Damages in this reach are mainly to basements of about 50 homes in Cranston and to equipment stored on several contractors storage yards in Warwick near the mouth of the brook. The height of floodwaters in this area is dependent upon the levels in the Pawtuxet as backwater flooding is very likely. In any event significant damages would not occur until the storm exceeded a fifty year event.

POCASSET RIVER

Since the early 1950's, this river has undergone drastic land use changes. Its former usage, agriculture, has now been replaced to a major degree by residential villages, commercial centers and industrial zones. This is especially true from Central Avenue in Johnston downstream to the Pawtuxet. Flood damages in the past years have been confined to back yards especially in the Fletcher Avenue area in North Cranston. Damages for the two zones of the Pocasset are discussed in the following paragraphs:

Pocasset River - Zone 6A

This reach runs from the headwaters in Johnston downstream to Reservoir Avenue in Cranston. Potential damage areas are as follows: Portions of Rotary Drive, LaFazia Drive, Center Street and Middle Street all in Johnston where many relatively new residential homes and an apartment complex can get basement flooding at an intermediate range flood. Areas in Cranston subject to significant damages at the intermediate level of flooding include an industrial-commercial center along Dyer Avenue, an apartment complex off Dyer Street, the Cranston Print Works, another industrial-commercial area located downstream of Cranston Street, a nursery off of Knollwood Avenue, as well as the Fletcher Avenue area.

Pocasset River - Zone 6B

This area includes the Reservoir Avenue area downstream to the merger point with the Pawtuxet, slightly below the Cranston sewage treatment plant. The entire zone is in the city of Cranston. Along Reservoir Avenue several commercial establishments are flood prone as are the Cranston Press at Pontiac Avenue and the Bowermann Construction Company. Residences and/or apartment complexes are subject to flooding along Longway Road,

Intervale Avenue and at Fordson Street. Problems in this zone are influenced to a high degree by the levels in the Pawtuxet River.

Roger Williams Brook - Zone 7B

This portion of the drainage basin's damage zone begins at Park Avenue and terminates at the Pawtuxet River. The problem in this area is due to backwater flooding of the Pawtuxet River rather than flooding of the brook. Some increases in stage heights does occur, however, due to inability of the basin to discharge the additional volume of waters. The main areas that would be damaged are the Atlantic Tubing Co. and Ciba-Geigy as well as a group of homes in El Durado Road.

Pawtuxet River Mainstem

Damages along the reaches of the mainstem are for the most part extremely high. There are many flood prone properties as each community (Warwick, Cranston and West Warwick) has numerous structures subject to inundation from storms ranging from a yearly event up to a standard project flood. There are in total around 2000 various types of structures subject to flooding in a major flood. Descriptions of damages by zone are discussed in the following paragraphs.

Zone 4

This area begins just downstream of the Natick Dam in Warwick-West Warwick and terminates at the Pontiac Dam in Warwick. Recent developments at or just above the one hundred year flood level had increased damage potential immensely. Areas subject to flooding for all practical purposes run the entire length of the zone. Areas of very high concentrated damages are the complex off of East Avenue in Warwick, an industrial area in West Warwick bounded by East Street, including its municipal treatment facility, the Midland Mall (however, only for major flood events), and the Warwick Mall area, its surrounding stores and the apartment complex.

Zone 5

Starting at the Pontiac Dam this reach of the Pawtuxet proceeds downstream where the river forms the city boundary between Cranston and Warwick. This zone ends at the location of the U.S.G.S. gaging station in Cranston (located in the Pettaconset Industrial Park). Damages in this reach are not as severe as in Zone 4. Most of the annual damages are sustained by the Pontiac Print Works building and the Bulova Watch Company. Both of these major firms can

sustain moderate damage at events as frequent as a 15-year storm. The Knight Street area has numerous flood prone structures but they consist mainly of relatively small commercial-service type operations.

Another major concern is this area, although not heavily damaged from a physical loss standpoint is the Warwick sewage treatment plant. The chlorine contact tank can be flooded by almost the yearly high water of the Pawtuxet. Although physical damage to the concrete tanks and operating equipment is minor, the unit is shut down and the unchlorinated, but treated effluent enters the Pawtuxet. Between the 5 and 10 year frequency floods, the settling tanks and aeration units can become inundated. Although the physical losses mount up with each incremental height of water, the total losses are still relatively minor. Of major significance is the fact that untreated wastewater from most of Warwick enters the Pawtuxet causing serious water quality degradation.

Zone 6

This reach runs from the U.S.G.S. gage down to the Elmwood Avenue Bridge in Warwick-Cranston and again, the river is the basic dividing line between these two cities. Damages in this zone are the smallest on all the main stem with the exception of Zone 3 which has virtually none. The Jefferson Avenue Industrial Park in Warwick consisting of Edwards Electronics, Ryder Truck Rental Co., and Colony Ford Co., does sustain heavy damages, with the initial losses starting at about a 10 year flood event. Also in this area is a major electrical transformer sub-station. At about a 50-year event the station would be inoperable and major rerouting of electricity to serve its areas would be necessary.

Another industrial park, Wellington Avenue, in Cranston has experienced past damages from the 1968 flood, a 10 to 15 year event. Some intensified use of the various mill outbuildings by a glass storage warehouse and Elmwood Sensors Co., will result in much higher recurring type losses. A moderate sized lumber yard on the opposite bank in Warwick is also very flood prone. Its losses depend on the amount of immovable material in storage at the time flooding occurred.

Zone 7

This area contains extremely high annual damages. From the termination point of zone 6 it runs down to the sewer trestle crossing the Pawtuxet at the Ciba-Geigy complex. Very high damages are possible at this location, particularly on the Cranston side. Damages would begin at about a fifteen year event. The Atlantic

tubing complex, which can also get flooded by backwater from Zone 7B is also likely to sustain heavy damages. This complex is also located in Cranston.

An extremely flood prone residential area is located in Warwick. Locally known as the Belmont or Norwood area, this site located off of Elmwood Avenue has about 50 homes that would sustain moderate damages at a hundred year flood. If a small dike, constructed by the Corps of Engineers in 1970 with Emergency Operations Funds did not exist the area would have been flooded annually. The dike, which was recently overtopped, provided protection to about a fifteen year flood level.

Zone 8

Damages in this zone are extremely heavy also. Flooding occurs from either the Pawtuxet River flows or due to the heights of the storm driven tides in Narragansett Bay. This last damage area extends from the sewer trestle at Ciba Geigy to the Broad Street dam at the head of Pawtuxet Cove. Other than the Pawtuxet Reservation which is conservation land in Cranston, and about 1/4 mile of high undevelopable land on the rivers edge between the dam and ITT Hammell Dahl Corp in Warwick, the remaining land is highly developed and extensively flood prone. The entire south bank (Warwick) other than the above mentioned high rivers edge is occupied by the Warwick Industrial Park. There are about 15 individual structures housing over 30 primarily industrial concerns in the complex. Each is at or within one foot of damage from the hundred year flood. Two concerns could receive especially high losses; Sealol and ITT Hammel Dahl.

RECURRING LOSSES

Damage surveys conducted in 1972 and 1973 indicate that a flood of an estimated 20-year frequency would have caused losses in excess of $1,500,000 in zones 4 through 8 along the main stem had there been no new development. Approximately 10 percent of these losses would have been residential, 16 percent commercial, and 70 percent industrial, with the remaining 4 percent in the utility, public, highway and erosion categories. Breaking these losses down by community, Warwick and Cranston would each receive about 47 percent of the total losses with the remainder in West Warwick. If a flood of an estimated 50-year frequency had occurred, the loss figures would have risen to more than $7 million with 5 percent in residential losses, 17 percent commercial, and 76 percent industrial, with the remaining 2 percent in other categories. Warwick would have sustained 69 percent of the losses, Cranston 29 percent and West Warwick the remainder.

Damages in the remaining zones for these two events are minor. For zones 2A (1 & 2) and 3, there is a total damage for a 20-year frequency event is less than $28,000 and for a 50-year event the losses would increase to less than $94,000. As damages along the Pocasset River (zones 6A and 6B) and Meshanticut Brook (zones 4A and 4B) for these two events would be minor and confined mainly to basement flooding, a detailed damage survey was considered unnecessary. Damages for the remaining zones were spot checked at a 100-year flood level with results indicating that losses would be negligible in comparison to the potential damages along the main stem of the Pawtuxet. Therefore, a detailed damage survey for any specified event in these reaches was considered unwarranted.

As previously stated, the effects of the increased "upstream" urbanization will result in higher damages to downstream areas even without any new development. As the peak discharges increase by 10 percent by 1990, the flood stages will rise, thereby creating higher monetary losses in 1990 will result in damages of more than $3,648,700. If the 50-year flood were to occur under the 1990 increased run-off conditions, the losses would rise to over $5,469,300. This is exclusive of any new construction or increased value in machinery or goods stored in any of the existing structures. All of these figures are at September 1978 price levels.

Average Annual Damages

Based upon the evaluation of structures that existed during the conduct of the damage survey and the increased runoff due to upstream urbanization, the average annual damages by zones are given in the following tabulation:

Average Annual Damages

Zone	Annual Damages
2A-1	600
2A-2	42,300
3	1,300
4	258,600
5	158,900
6	107,300
7	336,700
8	523,200
Sept. 1978 Price Levels	$1,428,900

ENVIRONMENTAL RESOURCES

GROUND WATER

Ground water favorability in the Pawtuxet River Basin has been mapped by the U.S. Geological Survey, the Rhode Island Water Resources Board and the Rhode Island Development Council. One of the most promising ground water acquifers lie in the southeastern Coventry-northeastern West Greenwich area bounded by the Flat River Reservoir, Tiogue Lake and Lake Mishnock (see Plate 1-2) and the other lies in eastern Cranston-southwestern Providence area located between the Pawtuxet and Woonasquatucket Rivers. Both aquifers occur in glacial outwash ranging in thickness from 50 feet to more than 100 feet. Small ground water supplies may be obtained in all of the remaining basin communities from glacial outwash deposits (generally less than 50 feet thick) or from bedrock.

Ground water in the South Branch drainage area aquifers is generally of good chemical quality, except for scattered concentrations of iron and manganese. The thickest outwash is located in the Mishnock Swamp area northeastward from the proposed Big River Reservoir. The Kent County Water Authority obtains nearly 3 mgd from wellfields at the southern and eastern flanks of this aquifer for use within the basin. The relatively thin outwash deposits within the proposed Big River Rerservoir area have been reported to be only partly saturated with water. Possible future export of ground water from the South Branch system could result in reduced natural discharges in the tributary streams as well as the South Branch. Injection of treated wastewater into aquifers was rejected in the SENE study report (see page 1-7) as an uneconomical method for aquifer recharge within the basin. However, land disposal by spray irrigation on appropriate forest lands in eastern West Greenwich was considered to be a future option which could aid aquifer recharge in the South Branch system.

Over 3 mgd are presently withdrawn from the Cranston-Providence aquifer by a major brewing company and other industrial users. It is unlikely that public-supply wells will be developed in this aquifer because of the high potential for contamination in this urban area the moderately high iron and chloride concentrations. However, increased industrial withdrawals may be expected from this outwash aquifer and the moderately productive underlying bedrock aquifer.

SURFACE WATER SUPPLY

The western half of the basin (specifically, the watershed areas in the six upper basin towns that drain into the Scituate and Flat River Reservoirs) and the western sections of Johnston and Cranston are served by private wells. The eastern and southern sections of Cranston, the southwestern corner of Providence, and the southeastern section of Johnston are serviced by the Providence Water Supply Board, which obtains all of its existing supply (72 mgd) from Scituate Reservoir. This reservoir is fed by five upstream reservoirs (Ponaganset, Barden, Westconnaug, Moswansicut and Regulating Reservoirs) in Glocester, Foster and Scituate. Other communities in the Providence system (all supplied by Scituate Reservoir) are Providence, East Providence, most of North Providence, and the southern and eastern sections of Smithfield.

The Kent County Water Authority uses wells in Coventry and East Greenwich that yield nearly 10 mgd and are supplemented by purchased water from Scituate Reservoir. It services West Warwick, East Greenwich, the southeastern corner of Scituate, the eastern section of Coventry and the northeastern corner of West Greenwich. Supplemental supply is also obtained from Carr Pond in eastern West Greenwich (safe yield 0.6 mgd/pumping capacity 1.2 mgd) A summary of the water supply sources for the Pawtuxet River Basin is shown in Table 1-1.

Water supply demand projections by the Rhode Island Water Resources Board, the Rhode Island Statewide Planning Program and the SENE Study have determined that the 72 mgd safe yield of Scituate Reservoir would be unable to meet 1985-1990 needs of the Providence system. In addition to expansion of existing service areas now served by the Providence system, it is anticipated that at least four Narragansett Bay communities (Barrington, Bristol, Warren and Warwick) will soon need supplies from an augmented Providence system. Several lower Narragansett Bay communities may also have to obtain future supplies from the Providence system in the event that yields from additional wells in the upper Pawcatuck River Basin are unable to accommodate the future water supply needs of southeastern Rhode Island.

Table 1-1

SUMMARY OF WATER SUPPLY
PAWTUXET RIVER BASIN

Water Supply Agency	Communities Served*	Population Served	Source of Supply	1975 Safe Yield, mgd
Kent County Water Authority			Ground Water	9.29
	Coventry	21,300		
	E. Greenwich	9,800		
	Scituate	1,400		
	W. Greenwich	700		
	W. Warwick	24,000		
City of Providence Water Supply Board			Surface Water	72.0
	Providence	168,000		
	Cranston	72,000		
	Johnston	16,800		
	N. Providence	20,310		
	E. Providence	49,900		
	Smithfield	11,220		
	Warwick	78,500		

* Communities not listed are served by private wells.

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BIG RIVER RESERVOIR PROJECT - PAWCATUCK RIVER AND NARRAGANSETT --ETC(U)

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Recognizing the above needs, the Rhode Island Water Resources Board has acquired the necessary reservoir lands and has initiated preliminary design studies for the proposed Big River Reservoir project. The project would be located on the Big River just upstream from the southern arm of the Flat River Reservoir. It would produce an initial yield of 20 mgd prior to diversion of flood skimming waters from the Flat River and other outer basin transfers. Ultimate allocation of storage at Big River for these diverted waters could reduce the net yield.

It is anticipated that future needs of the other communities in the basin could be met by development of wells in the Mishnock Swamp aquifer by the Kent County Water Authority (estimated yield 3 mgd) and by local water supply wells near the margins of the Scituate, Flat River and Big River Reservoirs.

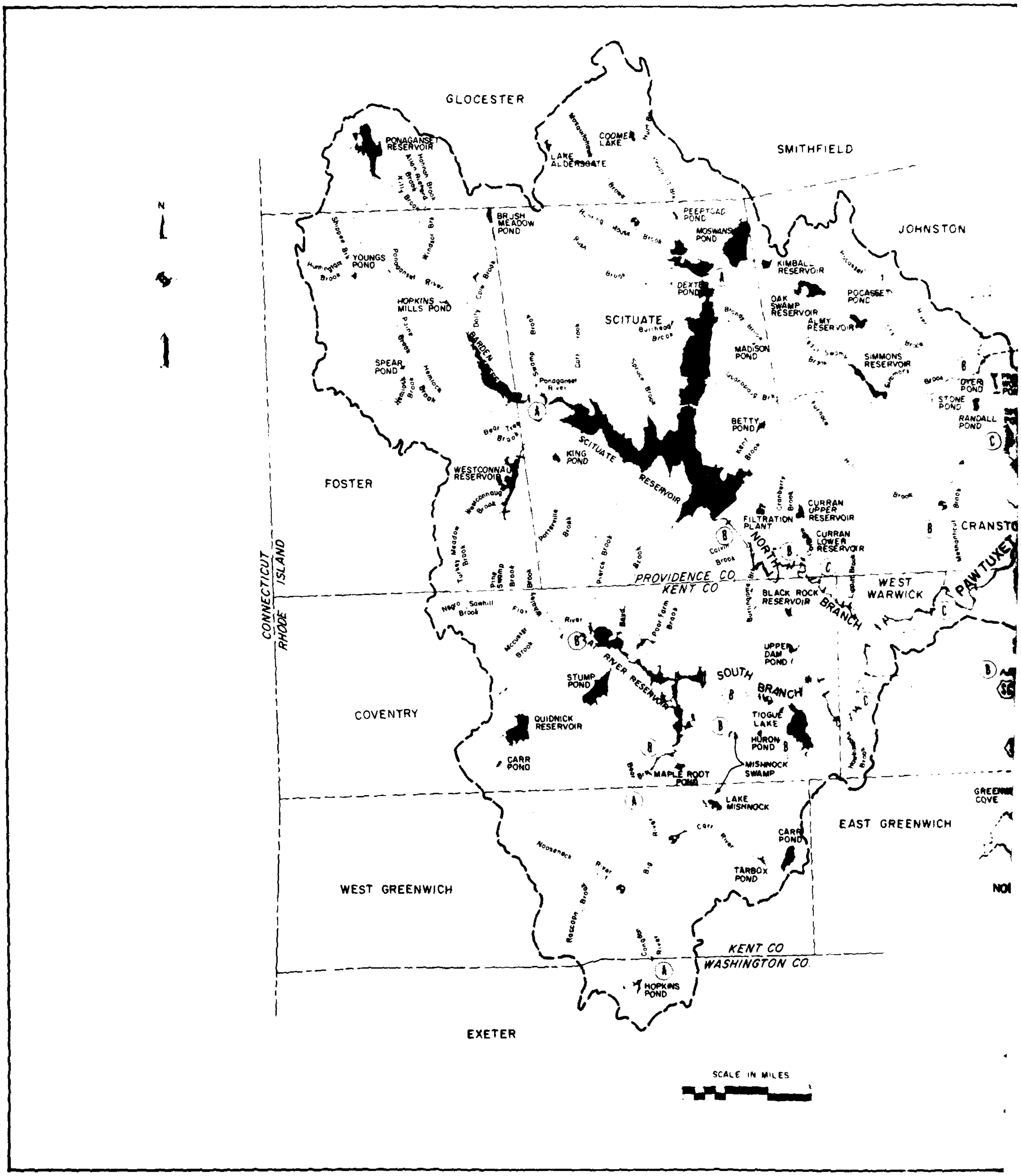
WATER QUALITY

The Pawtuxet River Basin is one of the most polluted in Rhode Island. Water quality in the Pawtuxet River Basin ranges from Class A (suitable for domestic water supply) at Scituate Resrvoir and Big River, Class B (suitable for domestic water supply with appropriate treatment and for swimming) for Flat River Reservoir and the upper reaches of the North and South Branches and Class C (suitable for fish and wildlife habitat and boating) for most of the main stem. While at times conformation to these classifications values they remain long term goals as established in 1977 by the Rhode Island Department of Health. A map showing these water quality classifications, is presented in Plate 1-4. Although the environmental objective of the Federal Water Pollution Control Act amendments of 1972 is to attain a minimum of Class B waters everywhere, economic and technologic limitations could preclude such attainment in the lower Pawtuxet River Basin.

Water quality degradation within the basin can be attributed to both rural and urban problems. The rural problems along the upper reaches of the North and South Branches can be attributed to the lack of municipal treatment facilities. Inadequate subsurface disposal units, incomplete onsite treatment of industrial wastes and frequent occurrence of low flow conditions contribute at times to high pollutional loadings.

The urban problems, along the lower reaches of the North and South Branches and the main stem are caused by urban runoff and the effluents from three municipal treatment facilities and several industrial and State institutional treatment facilities. Although all facilities provide the equivalent of secondary treatment, significant pollutional loadings remain in the discharges that further degrade the already impaired water quality caused by the upstream conditions. In addition, dams along the South Branch and the main stem cause sluggish flows and sedimentation of settleable solids, including organic wastes, thereby reducing dissolved oxygen levels.

There are four basic future needs within the basin: 1) provision of a regional treatment facility in Coventry or expansion and/or modification of the existing Warwick, West Warwick and Cranston treatment facilities; 2) addition of more sophisticated treatment components at existing treatment plants to remove any objectionable parameters; 3) expansion of existing treatment facilities as needed to handle future growth; and 4) resolution of the existing problem of insufficient low flows throughout the lower basin. Some of these needs may not be possible to resolve.



GLOCESTER
SMITHFIELD
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YOUNGS POND
HOPKINS MILLS POND
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ALMY RESERVOIR
POCASSET POND
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DYER POND
STONE POND
RANDALL POND
SCITUATE
DEXTER POND
MADISON POND
BETTY POND
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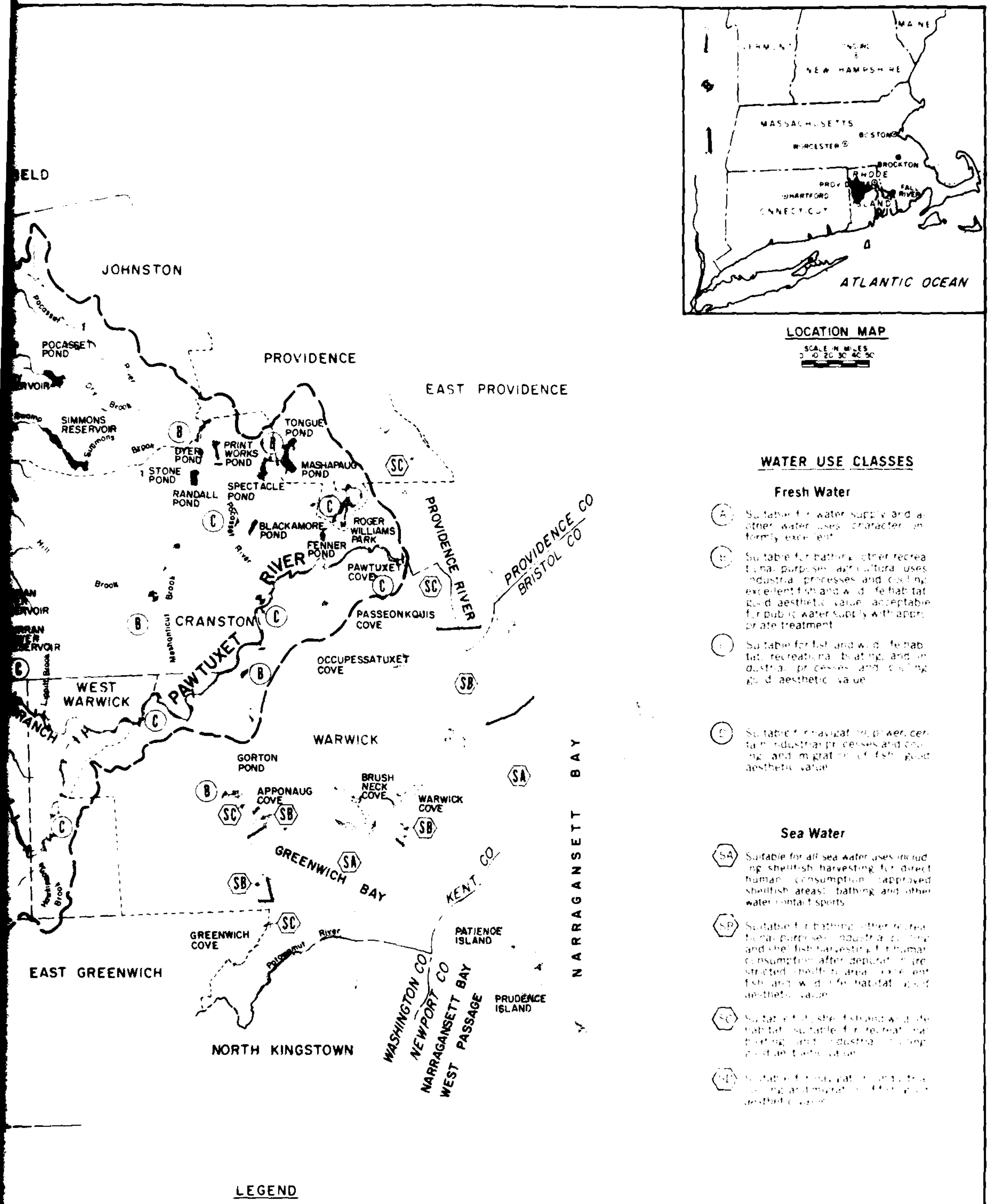

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

WATER QUALITY STANDARDS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 1-4

Water quality sampling is conducted periodically by the Rhode Island Department of Health. Water quality data in association with related projects for the basin have been collected by the Corps of Engineers and the Environmental Protection Agency (EPA) at two stations on the main stem and one station each on the North and South Branches. On the main stem, Station 1 is located at the Broad Street Bridge near the mouth of the Pawtuxet River, and Station 2 is at the Providence Street Bridge (Route 33) in West Warwick-Warwick, just upstream of the Natick Dam. Station 3 is on the South Branch at the Providence Street Bridge in West Warwick, just upstream from the confluence with the North Branch. Station 4 is located on the North Branch at the Main Street Bridge in West Warwick. Water sampling began in September 1975 and continued on a monthly basis to April 1976. The results are presented in Tables 12 thru 15 of the planning and hydrologic analysis in Appendix 4.

SOILS AND VEGETATION

Narrow bands of poorly drained alluvial soil are found in the bottom lands along many streams throughout the basin. Most of the adjoining lowland soil of Cranston and Warwick consists of the well drained Merrimac fine sandy loam of the granitic outwash plains. In the relatively low hills of Cranston, Johnston, West Warwick, West Greenwich and Exeter, the upland soil is prinicipally well drained Narragansett stone fine sandy loam.

The soil in the higher uplands of the the remainder of the basin, consists of the well drained Glocester stony fine sandy loam, which is one of the least fertile soils within Rhode Island. Sections of southern Scituate, southern Foster and northern Coventry have fairly extensive areas of rough stony land of Glocester soil material (boulders). The principal soils of the depressions in the northwestern quadrant of the basin are the poorly drained Scituate and Whitman stony loams. Many of the depressions in the southwestern quadrant of the basin consist of poorly drained Whitman stony loam where wetlands have formed.

Hinckley loam sand (a droughty soil) is frequently found in areas where kames were formed, such as in the Meshanticut Brook section of Cranston, the northeastern section of Scituate, the North Branch section of Scituate, the southeastern corner of Coventry, the northeastern corner of West Greenwich and the Foster Center area, for examples.

Information compiled by the U.S. Department of Agriculture indicates that dairy farming is the largest agricultural activity, followed by poultry farming, fruit growing (orchards) and market (truck) gardening. Considerable acreages of the lighter textured Merrimack and Narragansett soils that were cultivated in past centuries have been abandoned.

The heavier textured soils are well suited to market crops such as potatoes and small fruits. All of the granite soils of the basin are acidic and require lime for optimum yields for most crops or pasture. Berry crops could be cultivated in existing soils to good advantage. About 82 percent of the land in the six western communities is forested, about 3 percent is under intensive cultivation and about 4 percent is pasture land. In the east about 61 percent of Johnston is forested as are 23 to 31p ercent of the lands in Warwick, Cranston and West Warwick. About 14 percent of Cranston is under cultivation, but only 2 to 4 percent of West Warwick, Warwick and Johnston lands are cultivated. Pasture land ranges from 3 percent in West Warwick to 7 percent in Cranston.

The forest community in the eastern half of the basin is composed primarily of hardwoods, with scattered stands of pines and cedars. The deciduous growth consists principally of oaks (red, white, black and scarlet) and occasional stands of gray birch, aspen, black, cherry, maple trees as well as sumac, grape and bayberry. The wooded swamps contain red maple, swamp white oak, red ash, elm, aspen, willow trees along with swamp azalea, witch hazel, high bush blueberry and other shrub growth. Most of the western half of the basin contain conifers, either in pure of mixed stands. White and pitch pine are dominant with frequent stands of red and white cedar. Hardwood stands include ash, birch, elm, hickory, maple, oak, poplar and willow.

The largest wetland area within the basin is Mishnock Swamp in southeastern Coventry and northeastern West Greenwich. Other extensive wetland areas occur along the Big, Nooseneck and Carr Rivers that drain as a system into the Flat River Reservoir. Numerous smaller wetlands occur along the lower reaches of the Pocasset River in southeastern Cranston and along the western tributaries of the Pocasset River and, Meshanticut Brook in western Johnston and western Cranston, respectively.

HUMAN RESOURCES

POPULATION CHARACTERISTICS

The estimated 1970 population residing within the basin limits was 180,000. Based on a basin area of 230 squre miles, the population density was about 782 persons per square mile. The more heavily populated eastern third of the basin contains estimated population densities as follows:

Community	Population Density (people/square mile)
Coventry (eastern quarter only)	884
Cranston (nearly 100%)	2,603
Johnston (western 77%)	598
Providence (southwestern 18%)	8,182
Warwick (northern 23%)	2,087
West Warwick (northwestern 62%)	3,750

Using 1970 data, the average population density for the selected portions of these six communities that are located in the eastern portion of the basin (162,100 persons residing in 78.9 square miles) was 2,054. Warwick, Cranston and West Warwick with total estimated population of 110,400 persons residing in 41.7 square miles have a population density average of about 2,647 persons per square mile.

Information was compiled concerning residents living in 11 of the 13 communities located entirely or partially within the basin. Because the towns of Smithfield and East Greenwich have less than one percent of their land area located within the basin, no information was compiled concerning residents of those two towns.

Data concerning population, education, income, employment skills and housing are presented in Tables 1-2 through 1-6. In 1970, 7.8 percent of the 948,844 residents of Rhode Island were foreign born and 25 percent of the population had foreign or mixed parentage. Roughly one-third of those ethnic backgrounds were Italian or Canadian. British, Irish, Spanish, Portuguese, Polish and Russian origins accounted for another third, with all other origins accounting for the remainder. About 3.3 percent of the State population is non-white. The black population is predominantly native born, slightly more than half reside within the city of Providence. Because community growth is influenced to a large degree by available land, services, and capital, information concerning population projections and community development is presented in later paragraphs near the end of this report section.

TABLE 1-2

POPULATION PROFILE

Community	Foreign Born (%)	Foreign or Mixed Parentage (%)	Median Age (Years)	Median School Years Completed 1)	Completed High School 1) (%)	Completed College 1) (%)	Per Capita Income ($)	Family Income 2) ($)
Coventry	4.3	19.2	25.8	11.7	47.3	4.9	3,263	10,630
Cranston	7.9	30.[illegible]	34.9	12.1	51.7	6.1	3,942	10,778
Exeter 3)	1.5	N.A.	26.4	9.1	34.2	5.5	1,944	9,327
Foster	4.3	N.A.	29.4	12.2	57.4	9.3	3,163	9,838
Glocester	4.0	N.A.	29.0	12.0	51.1	9.6	2,988	10,175
Johnston	6.0	32.7	29.6	10.9	38.6	4.6	3,302	10,259
Providence	10.2	26.4	32.1	10.9	40.6	4.7	3,464	8,430
Scituate	3.0	N.A.	30.9	12.1	53.0	8.3	3,199	10,652
Warwick	4.7	22.8	30.1	12.2	55.8	6.5	3,766	11,006
West Greenwich 4)	2.7	N.A.	26.5	11.0	N.A.	N.A.	N.A.	9,796
West Warwick	9.3	28.7	28.9	10.4	37.1	5.2	3,336	9,485
Rhode Island	7.8	25.0	31.8	11.5	29.0	5.4	3,473	9,736

NOTES:
1) Persons aged 25 years or over.
2) 1967 Dollars.
3) Exeter is a small town which includes a State for mentally retarded that is reflected in this population profile.
4) Detailed educational data for West Greenwich is not available, but 68 and 15 percent of adults entered high school and colleges, respectively.

TABLE 1-3

EMPLOYMENT SKILLS BY INDUSTRY DIVISION
1970 Census by Place of Residence
(By Percentages)

Community	Mfg.	Trade	Services	Gov't.	Educ.	Hosp.	Constr.	Finan. Insur. R. Est.	Transp. Commun. Utilities	Farming and Fishing
Coventry	44.2	14.2	11.1	9.0	4.5	5.3	5.9	3.2	4.2	0.4
Cranston	30.8	21.3	11.9	6.6	6.9	5.8	6.0	5.5	4.5	0.7
Johnston	38.9	21.5	8.3	4.5	5.4	3.2	8.6	4.3	4.3	1.1
Providence	32.8	17.1	15.9	6.3	10.2	4.4	4.3	4.3	8.8	0.5
Warwick	32.8	20.4	9.8	7.1	6.1	6.6	5.7	5.1	5.8	0.6
West Warwick	40.2	16.9	6.9	9.8	1.5	6.6	5.3	4.7	6.6	[illegible]
Peripheral Communities*	5.0	22.5	20.2	13.2	24.1	**	6.3	**	5.0	**
Rhode Island	35.8	19.0	10.4	6.2	7.7	5.9	5.5	4.3	4.7	1.0
United States	25.8	19.8	9.9	16.7	1.6	4.1	4.4	4.9	6.0	6.8

* Includes towns of Exeter, Foster, Glocester, Scituate and West Greenwich.

** Included under miscellaneous skills (3.7%).

TABLE 1-4

HOUSING OCCUPANCY
(1970 Units)

Community	Total Units	Vacant Units	Median Value* ($)	Owner Occupied (%)	Renter Occupied (%)
Coventry	6,970	81	17,900	79.1	20.9
Cranston	27,859	1,169	18,600	46.0	49.8
Exeter	795	91	15,300	67.0	21.5
Foster	839	68	15,700	78.3	13.6
Glocester	1,620	81	16,800	80.2	14.8
Johnston	5,212	184	18,600	64.3	32.2
Providence	68,132	4,978	16,800	33.2	59.5
Scituate	2,302	119	19,700	78.1	16.8
Warwick	26,826	892	17,100	79.2	17.4
West Greenwich	621	62	15,900	65.7	24.3
West Warwick	8,113	307	17,300	52.4	43.8

* Owner-occupied year-round housing (median value for Rhode Island is $18,200 in 1967 dollars).

TABLE 1-5

HOUSING TYPES
1970 Units

Community	Total Units	Single Family (%)	2-4 Family (%)	5-Plus Family (%)	Mobile Units (%)
Coventry	6,970	82.1	13.9	4.8	3.3
Cranston	27,859	64.8	28.4	6.6	few
Exeter	795	69.6	4.4	2.1	23.9
Foster	839	87.5	4.8	1.5	6.2
Glocester	1,620	84.5	9.4	-	6.1
Johnston	5,212	74.8	22.5	2.4	0.3
Providence	68,132	21.7	57.9	20.4	few
Scituate	2,302	86.9	10.7	1.0	1.4
Warwick	25,826	86.0	7.9	5.7	0.3
West Warwick	8,113	46.6	40.0	13.4	few

NOTE: The majority of the 621 dwellings in West Greenwich are single family structures, but detailed breakdown is unavailable.

TABLE 1-6

HOUSING VINTAGE
(Period Built)

Community	1939-earlier (%)	1940-1949 (%)	1950-1959 (%)	1960-1970 (%)
Coventry	29.6	10.4	22.9	37.1
Cranston	48.4	12.5	20.4	18.7
Exeter	23.4	10.7	23.8	42.1
Foster	49.5	11.4	19.7	19.4
Glocester	41.4	11.7	18.0	28.9
Johnston	39.8	11.0	24.4	24.8
Providence	80.7	7.5	6.8	5.0
Scituate	37.0	9.4	24.6	29.0
Warwick	34.2	14.8	29.7	21.3
West Warwick	55.3	8.7	15.8	20.2

NOTE: Data for West Greenwich is unavailable.

Population projections for the region were developed in 1972 by the Bureau of Economic Analysis of the U.S. Department of Commerce. Based on this data, it is projected that the population density in the upper Pawtuxet Basin will increase from 315 people per square mile in 1970 to 540 per square mile in 1990. This growth is expected to result in a 50 percent increase in impervious cover from about 8 to 12 percent, and result in a 10 percent increase in peak discharge. At least a comparable percent increase is expected between 1990 and 2020. It should be noted that some population figures and densities in this section deal with the entire basin, while others deal with the headwater tributaties, Meshanticut Brook and the North and South Branches only.

DEVELOPMENT AND ECONOMY

EARLY DEVELOPMENT

Prior to the arrival of European settlers, Rhode Island was inhabited by five Indian tribes of Algonquin (Algonkian) stock. The Narragansett (Nahiganset) Nation occupied most of the Narragansett Bay - Pawtuxet River Basin area, with the Niantic, Nipmuc, Pequot and Wampanoag tribes occupying surrounding areas. Except for skirmishes with rival tribes, the Narragansetts were peaceful farmers, hunters and fishermen. Historians have documented that European navigators explored the Narragansett Bay area in 1524 (Giovanni da Verrazano, an Italian sailing for France) and 1614 (Adrain Block, Dutch navigator) with the possibility that Miguel de Cortereal (Portuguese navigator) sailed along the entrance to the bay in 1511.

The first European settlement was established in 1636 when Roger Williams fled the Massachusetts Bay Colony is search of religious and political freedom. He established a new colony at Providence. Most of the northern half of the present State of Rhode Island was purchased by Williams from the Narragansett Indians. This area extended generally from Massachusetts on the north to the northern border of Coventry on the south, and from Connecticut on the west to the Blackstone River on the east.

Settlements in other sections of the Pawtuxet River Basin soon followed. In 1638, friends of Roger Williams settled an area at the Cranston side of the river mouth known as Pawtuxet Purchases. A third settlement was founded in 1642 at Shawomet at the head of old Warwick Cove in Warwick, when another Providence group purchased land from the Mishaomet (Shawomet) branch of the Narragansetts. Coventry was established in 1643 as part of the Shawomet Purchase. Although not documented by specific dates, settlements also occured within the present towns of Glocester, Foster, Scituate, Smithfield and Johnston, as part of the expansion

of the Providence Colony. At the southern end of the basin, Exeter was part of a colony established in 1641 (now called North Kingstown) that was incorporated in 1674 as part of a larger area known as King's Towne.

All of the Rhode Island colonies maintained good relations with the Narragansetts until 1675, when the Narragansetts joined forces with Philip (Metacomet), chief of the Wampanoags. Philip believed his tribe had received unfair treatment from the Massachusetts Bay and Plymouth colonists. Many white settlers and Indians were killed and towns burned during King Philip's War until Philip suffered a major defeat in the Great Swamp Fight (1675) in King's Towne. He was killed the next year near Mount Hope (now Bristol), a village southeast of Providence. In 1677 following the war, the town of East Greenwich was incorporated. It then included the present West Greenwich area.

During these early development years, the coastal region offered fertile farming and grazing lands. Slaves frequently worked the fields as a result of the molasses-rum-slave trade that had developed at the nearby Rhode Island ports of Newport and Westerly. All of the scattered villages within the basin were principally agricultural communities. Most products were handmade. Early industries included gristmills and sawmills at a few waterpower sites and an iron foundry in the southeastern section of Scituate. Limited mining of bog iron ore, soapstone and granite occurred in the Cranston-Johnston area. Industrial development did not occur until the early 1800's, after the development of textile and silver plating industries in the Providence-Pawtucket area to the northeastward. A small fishing industry developed in the Cranston-Warwick area, but the seaport of Providence served the commerce needs of the basin, as it does today.

During the early 1800's, numerous waterpower sites were developed for the manufacture of textiles in Cranston, Johnston, West Warwick, Coventry and the southeastern section of Scituate. Jewelry-silverware industries also developed in Providence, Cranston and Johnston. Over 30 small villages developed around the industrial sites along the Pawtuxet River, the North and South Branches, and along the Pocasset River. Subsequent development of fabricated metal industries occurred in Cranston, Warwick, Providence, Johnston, West Warwick and Coventry.

LATER DEVELOPMENT AND URBANIZATION

During the Industrial Revolution, the western sections of Warwick were settled near available waterpower sites. Similarly the eastern section of Coventry and the southeastern section of Scituate were settled at that time. Attracted by cheap land and the availibility of water, wealthy families built textile mills

along the river attracting workers to the area. Separate villages grew around each major group of mills and became more or less independent communities. Each set of mills was worked primarily by members of one ethnic group and became the economic center of a community with a distinct ethnic flavor. As employers searched for cheaper labor, British mill workers were displaced first by the Irish, then by French-Canadians, Polish, Italians and most recently, Portuguese workers. New communities, established through sheer number, developed organizations such as the ethnic church, encouraging a sense of separateness long after the residents spoke a common language and had ceased to be competitors. With the mills offering secure employment, population in the area concentrated around them. This growth of local neighborhoods was sufficiently strong in later years to preclude the development of "downtown" or central business centers in the basin communities, except in Providence.

During the period between the Civil War and World War I, the lower basin area prospered and the nearby Johonston-Providence villages along the Woonasquatucket River, the Warwick-Coventry-Scituate villages and the Cranston villages along the Pocasset River and the lower main stem also continued to grow steadily. In 1913, the industrial villages of Warwick along the North and South Branches and all of the industrial villages along the upper main stem except Pontiac separated from the main area of Warwick and formed the separate town of West Warwick. West Warwick was industrial, while Warwick remained largely a series of unconnected agricultural and recreational villages in a less developed atmosphere.

Although the area economy propsered during World War I, the extensive textile industry in the lower basin communities started to decline during the 1920's because of competition from the many textile firms that had moved to the south. During the national depression that prevailed during the 1930's, there was relatively little growth within the basin. The major waves of immigration had ended and there were limited job opportunities in the basin.

A turning point in the regional economy occurred in the early 1940's during World War II when a major economic uplift was experienced, especially in the mills that could be converted to war material production. A shift toward many new industries occurred: electronics, precision instruments, electrical machinery, fabricated metals, plastics and synthetic fibers. In addition, many new jobs were created at large naval installations at nearby North Kingstown (Davisville and Quonset Point) and at Newport Naval Base. The extension of the State-operated public transit system into the Providence suburbs and the trend toward commuting by automobile were significant factors in the postwar growth of the lower basin communities.

Although Providence is still the largest city (approximately 180,000 population) and the principal place of employment (approximately 131,000 jobs) within the State, two conditions have developed since 1950. One is the outward migration of residents who prefer to live in larger homes on larger lots within the suburbs. The second is the decreasing availability of large blocks of vacant land within the city which negates the expansion of existing industries or development of new industries that usually require sizeable single-floor plants for efficient operation. This second condition was partially offset during the mid-1960's by converting a rundown warehouse area at the headwaters of Mashapaug or Roger Williams Brook in southwestern Providence into a modern industrial park that is currently occupied by jewelry, footwear, plastics and printing firms.

Population growth figures (1950-1970) for the basin communities and population projections for 1990 and 2020 are shown in Table 1-7. Excluding Providence which lost population (69,000) between 1950 and 1970, population in the other ten communities listed in the table increased from 150,[illegible]72 in 1950 to 247,649 in 1970, representing a 64 percent increase. Between 1950 and 1970, population doubled in the eastern sections of Coventry and Scituate, nearly doubled in Warwick and Johnston, increased by one-third in Cranston and by one-fifth in densely populated West Warwick area increased. Except for the older, densely established sections of eastern Johnston, eastern Cranston, northern Warwick, and western West Warwick, the lower basin area attracted many new residents to the broad open areas available for tract development, the accessibility of a good highway system and the desirability of suburban living close to Narragansett Bay. Although only a few pockets of new residential growth occurred within the Pawtuxet flood plain, two massive shopping malls (125 stores) were built in the Warwick flood plains and a number of manufacturing and service industries were built or expanded in the Warwick, Cranston and West Warwick flood plains. A summary of 1970 land use in each basin community is presented in Table 1-8.

Although the lower basin has experienced substantial industrial and commercial growth since World War II, Rhode Island has generally experienced substantially higher unemployment than the national average. As shown by Figure 1-1, Rhode Island has experienced only one boom period since World War II, the period between 1965 and 1970. Since World War II, however, the State has endured four major recessions: 1948-1951, 1953-1955, 1957-1959, and 1974-1976. During the most recent recession, the Rhode Island unemployment rate remained roughly twice the national average. Rhode Island has been a marginal producer, quick to feel the effects of economic downturn and slow to reap the benefits of prosperity. Until recent years, there has been a prepouderance of small manufacturing firms with limited resources and growth potentials. Also, Rhode Island

TABLE 1-7

COMMUNITY SIZE AND POPULATION GROWTH

Community	Area * (Sq. Mi.)	Percentage Within Basin	1970 Density	1950 Population	1960 Population	1970 Population	1990** Population	2020*** Population	AVERAGE ANNUAL GROWTH 1950-1970 (Percent)	1970-1990 (Percent)	1970-2020 (Percent)
Coventry	62.2	66.10	369	9,869	15,432	22,947	32,100	40,200	4.4	1.7	1.2
Cranston	28.6	99.98	2,509	55,060	66,766	74,287	86,000	107,700	1.5	0.8	0.7
Exeter	58.2	5.66	56	1,870	2,298	3,245	4,800	7,000	2.7	2.[illegible]	1.6
Foster	51.4	59.26	51	1,630	2,097	2,626	3,800	5,900	2.4	1.9	1.7
Glocester	55.3	25.09	93	2,682	3,397	5,160	7,200	10,000	3.4	1.7	1.3
Johnston	23.7	77.57	825	12,725	17,160	22,037	31,500	39,400	2.8	1.7	1.1
Providence	18.1	18.33	9,896	248,074	207,498	179,116	187,000	195,000	-1.6	0.2	0.2
Scituate	48.8	100.00	153	3,905	5,210	7,489	9,200	12,400	3.4	1.0	1.0
Warwick	34.9	22.96	2,398	43,028	68,504	83,694	105,900	132,600	3.4	1.2	0.9
West Greenwich	50.6	46.40	36	847	1,169	1,841	3,200	4,800	3.9	2.9	2.0
West Warwick	8.3	62.22	2,930	19,096	21,414	24,323	26,700	33,400	1.3	0.8	0.7

* Land area as compiled by U.S. Bureau of the Census (excludes inland water areas)

** R.I. Statewide Planning Program 1990 Projections

*** OBERS Series E 2020 Projections

TABLE 1-8

LAND USE

Community	Land Area*	Inland Water*	Total Area*	Water (%)	Open Wetland (%)	Forest Wetland (%)	Forest ** (%)	Agriculture *** (%)	Industrial-Commercial (%)	Residential (%)	Transportation (%)	Other (%)
Coventry	62.2	2.6	64.8	[illegible]	1.5	4.5	69.7	7.6	0.9	8.5	0.2	2.9
Cranston	28.6	1.4	30.0	5.0	2.6	1.4	27.6	18.8	4.9	25.4	4.1	10.2
Exeter	57.6	0.6	58.2	1.0	1.1	3.9	79.3	8.1	0.1	2.3	-	2.1
Foster	51.4	0.8	52.2	1.6	0.7	5.0	81.0	8.4	0.2	2.4	-	0.7
Glocester	55.3	1.9	57.2	3.9	1.0	5.4	78.6	6.6	0.2	3.7	-	0.8
Johnston	23.7	0.7	24.4	3.0	3.5	2.0	59.1	9.3	2.0	16.0	1.7	3.4
Providence	18.1	1.9	20.0	9.5	0.2	-	4.1	1.0	17.3	41.5	9.1	17.7
Scituate	48.8	6.3	55.1	12.9	0.6	2.2	72.3	5.8	0.2	5.8	-	0.2
Warwick	34.9	0.9	35.8	2.6	1.5	0.7	24.6	9.5	5.5	37.8	6.7	11.0
West Greenwich	50.6	0.6	51.2	1.2	1.3	2.1	85.8	4.8	0.1	2.3	0.6	1.8
West Warwick	8.3	0.2	8.5	2.4	1.0	2.6	31.5	12.5	6.8	34.7	1.4	7.1

* U.S. Bureau of the Census data in square miles.
** Forest area excluding forest wetlands.
*** Intensive and extensive agriculture.

has one of the lowest educational attainment levels in the nation, which has restricted many residents to low paying jobs. The lack of public services (water, sewerage, power and transportation) for much of the acreage zoned for industry has also been a restricting factor.

As shown in Table 1-9, textiles and jewelry-silverware have continued to be major industries in Coventry, Providence, Scituate and West Warwick. However, trade, diversified manufacturing, government (including education) and service industries represent the major employment classifications in most of the other basin communities. The city of Providence, as shown by Table 1-10, continues to offer the principal employment opportunities for most basin residents. While substantial employment opportunities are available in Warwick, Cranston, West Warwick and Coventry, many basin residents commute to jobs in the Providence, North Kingstown, Newport and eastern Connecticut areas. With the phasing-out of Rhode Island's major naval installations at North Kingston and Newport in 1972-1974, 20,000 military personnel and 10,000 civilian jobs were eliminated from the economic base. In addition to the loss of primary jobs, economic hardshops were generated in supporting industries such as retail trade and services. Some of this loss has been offset by the utilization of a portion of North Kingstown facilities for the construction of nuclear submarines by private industry. This should result in several thousand skilled jobs for metal workers and machinists. State and local officials are endeavoring to attract additional private industry to the area.

While all of the lower basin communities have scattered attractive residential areas, urban sprawl has radiated outward from the earlier mill villages. Some commercial development has clustered around these older villages, but extensive commercial strip development has occurred along the main thoroughfares. Within the past 10 years, two major shopping malls and two large shopping centers were built along or near the main stem in Warwick, making that area a regional shopping center for over half of the State. Several smaller shopping centers have been built in other communities.

Most of the older industrial development is located at existing or former waterpower sites along the main stem and many of the tributaries. More recently, industrial growth had tended to be more clustered as strip development along service roads or railroads, and more recently in industrial parks.

The Pawtuxet River Basin is well served by all types of transportation. The Cranston-Warwick area represents one of the major hubs in the Rhode Island highway network system. It includes I-95 (one of the principal routes connecting New York, Providence

TABLE 1-9

PRINCIPAL EMPLOYMENT WITHIN EACH COMMUNITY

Community	Employment Classifications (1) (2)
Coventry	Textiles, trade, government, electrical wire and connectors, chemicals, glass containers.
Cranston	Trade, government, service industries, construction, food products, chemicals.
Exeter	Government, trade, service industries, transportation and utilities, fabricated metal products, agriculture.
Foster	Government, service industries, trade, agriculture, (no manufacturing).
Glocester	Government, trade, service industries, agriculture, transportation and utilities, construction.
Johnston	Trade, government, service industries, jewelry and silverware, textiles, fabricated metals.
Providence	Trade, jewelry and silverware, government, finance (3), service industries, fabricated metals.
Scituate	Textiles, government, trade, service industries, construction, agriculture.
Warwick	Trade, government, service industries, machinery, electrical machinery, fabricated metal products.
W. Greenwich	Government, service industries, trade, construction, agriculture, steel products.
W. Warwick	Trade, textiles, government, service industries, scientific instruments.

(1) Listed in order of total employment.
(2) Government includes municipal educators.
(3) Finance also includes insurance and real estate.

CIVILIAN LABOR FORCE UNEMPLOYMENT
1947 – 1975 ANNUAL AVERAGES

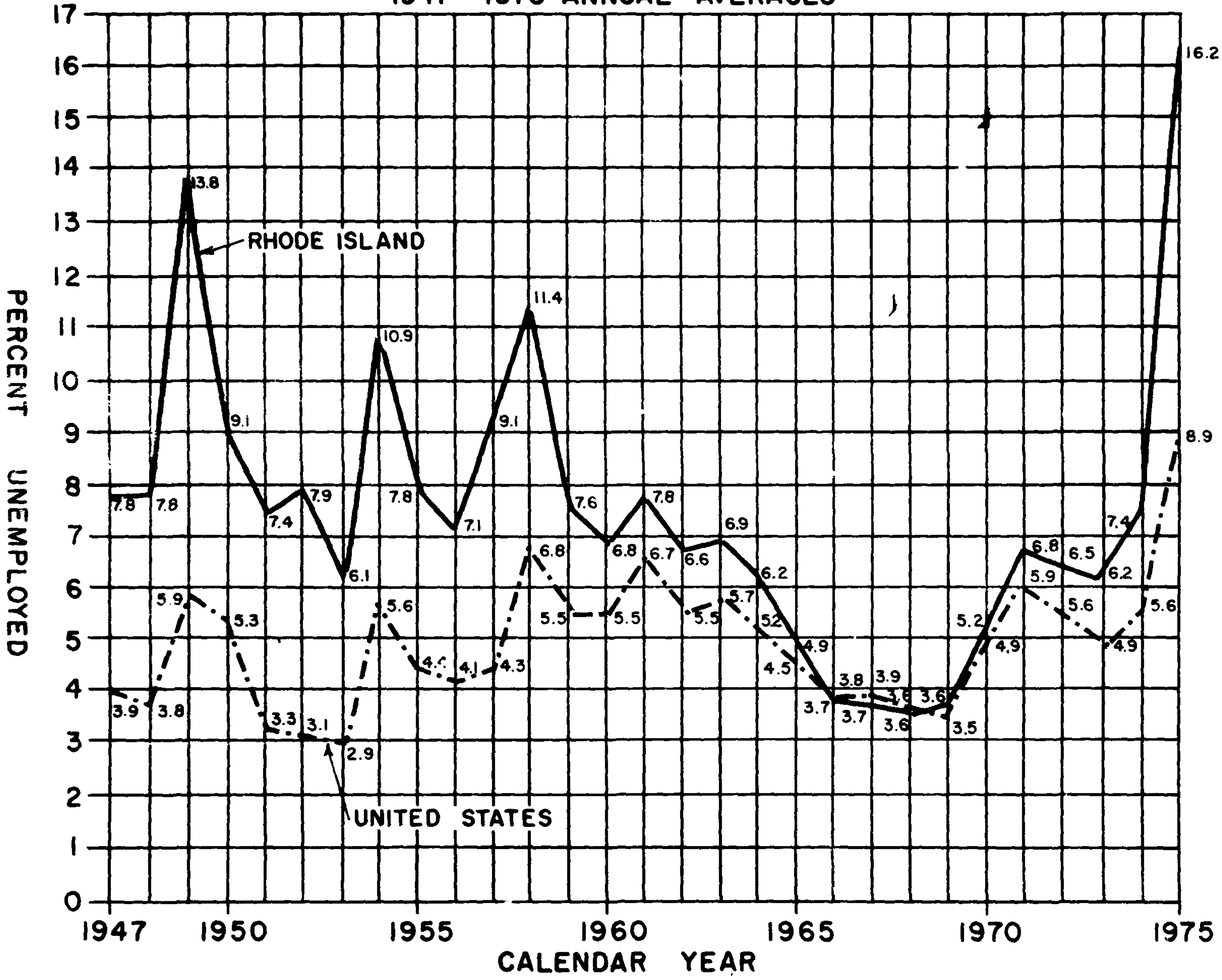

FIGURE 1-1

TABLE 1-10

TOTAL EMPLOYMENT WITHIN EACH COMMUNITY

Community	Labor Force (1)	Percent Female	Percent Male	Total Employment within Community (2)
Coventry	12,609	27.1	72.9	4,658 (1972)
Cranston	31,210	40.1	59.9	16,713 (1968)
Exeter	2,420	49.1	51.9	211 (1971)
Foster	1,861	51.0	49.0	226 (1971)
Glocester	3,662	51.1	48.9	625 (1971)
Johnston	13,038	28.3	71.7	3,631 (1968)
Providence	58,091	33.8	76.2	130,832 (1972)
Scituate	5,520	51.7	48.3	920 (1974)
Warwick	36,312 (1)	33.0	67.0	24,400 (1974)
W. Greenwich	734	33.7	66.7	[illegible]49 (1973)
West Warwick	15,569	29.8	70.2	6,159 (1971)

(1) 1970 civilian labor force data, except 1974 data for Warwick.

(2) Estimated manufacturing employment within the river basin limits is as follows: Providence (6,200), Cranston (6,000), Warwick (4,300) and West Warwick (3,000).

and Boston), I-295 (the southwestern end of the outer belt highway around Providence) and to high-speed connectors (RI P-37 and the connector to the State Airport in Warwick). At Warwick, I-95 swings southwestward through the southern basin communites of West Warwick, East Greenwich, West Greenwich and Exeter. Other important routes to the south, U.S. 1 and RI routes 2 and 4, all connects at Warwick and provide access to the lower Narragansett Bay and South County summer vacation areas.

The northern part of the basin is served principally by U.S. 6, the primary east-west route between Hartford and Providence. It connects on the east at Providence with I-195 which services the Fall River-New-Bedford-Cape Cod area. This route connects on the west with the Connecticut Turnpike and I-84. The northeastern end of the basin is also serviced by the southern end of the Providence inner belt highway (RI route 10 and I-195). An extensive system of secondary State roads serves the other sections of the basin.

The basin is served by approximately 120 contract trucking firms that have major teminals in Providence (about 4 miles north of the river mouth) and East Providence. Some of these firms have additional teminals in Warwick, Cranston and Johnston.

Four interstate bus companies, with central terminals at Providence, provide regular runs to Boston, southeastern Massachusetts, Worcester, Springfield, Hartford, New Haven and New York City. Interstate bus runs within the basin are operated principally along I-95 and U.S. 6. Regional bus service is provided by the State-operated Rhode Island Public Transit Authority, which has regular runs from Providence to Warwick, Cranston, Johnston, West Warwick and the Washington section of Coventry. Additional local bus service is provided between Coventry and Warwick and between Exeter and East Greenwich.

Bulk freight service is proivded by ConRail, which has a major freight terminal in Providence and small freight yards in Cranston and Warwick. The main line extends from Providence southerly through Cranston, Warwick and Westerly (RI) and then westerly to New Haven and New York. Two branch lines extend from Cranston, one to the vicinity of the Pontiac Section of Warwick and the other to West Warwick and the Washington Section of Coventry.

Regular passenger service to Boston, New York and Washington is made by Amtrak runs along the main line. Express runs stop only at Providence. Other runs include stops at West Kingston (in South Kingston) and at Westerly.

Most of the air passenger and air freight needs of Rhode Island are handled at the State-operated T.F. Green Airport, located near the center of Warwick. Regular passenger and cargo service is provided

by five major airlines that operate over 100 flights daily at the airport. Charter service is provided at Warwick and also at the North Central State Airport, located along the Smithfield-Lincoln line about 7 miles northwest of Providence.

Most of the waterborne commerce needs of the basin are served by the nearby Port of Providence, which has a 40-foot deep main ship channel. The port has 21 terminals: 15 cargo and oil terminals in Providence and 6 oil terminals in East Providence. A few commercial fishing boats (shellfish) operate out of Pawtuxet Cove (at the river mouth) or out of Old Warwick Cove (at the northeastern end of Greenwich Bay), but their catches are usually unloaded at Wickford Harbor or other harbors.

LAND USE

Coventry

Coventry is the largest town in the State with 62.25 square miles of land. Though the 1970 total population was fairly high at 22,947 persons, the population density is fairly low at 369 persons per square mile. Coventry is growing very rapidly, as evidenced by a 132 percent increase in the past two decades.

Coventry has less than one percent of its land in industrial and commercial land while the county and the State averaged twice as much. However, since Coventry is 3.5 times larger than the average town in the State, the one percent still involves a fairly large amount of land. There are 103 acres of heavy industry and 207 acres of light industrial and commercial land. Nine percent of the town is in residential land compared to county and State figures of 15 and 13 percent respectively.

Only 7 percent of Coventry is in agriculture; 2 percent is in tilled land, and 85 acres are in cranberry bogs. Three-quarters of Coventry is forested while the State averages 59 percent in that use.

Cranston

Cranston is part of the Greater Providence industrial and commercial complex which includes Providence, North Providence, East Providence, Pawtucket, Central Falls, Warwick and West Warwick. This large industrial and commercial complex includes all the high density population towns in the State except Woonsocket, Middletown and Newport. Whereas Providence, Central Falls and Pawtucket are all losing people, Cranston has increased its population by 33 percent from 1950 to 1970. Its population was

73,037 and its populat[illegible] is 2,520 persons per square mile. In area, Cranston has [illegible] of land.

[illegible] percent of Cranston i[illegible] industrial and commercial land while the State has only 2 percent. Heavy industry covers 166 acres of land and light industry is located on 169 acres. All kinds of activities are located on 59[illegible] acres in the town, so Cranston has nearly twice as much commercial land as industrial land.

Twenty-seven percent of the town is residential. A very large 57 percent of the residential land is the old-fashioned, high density type with houses on lots with 50 feet of street frontage. Thirty-two percent of the residential land is the medium density type while the rest of it is light density types.

For a fairly densely populated city, Cranston has 21 percent of its area in farmland and 15 percent of the city is still tilled. This open green space adds greatly to the scenic quality of the city. Twenty-nine percent is forested and 5 percent is wetland. Fifty-five percent of the city is farm, forest or wetland, so for a densely populated city, Cranston has a large amount of green space available. Cranston is likely to continue to grow as it has in the past because it is part of the Greater Providence area, and yet it offers a pleasant environment to keep its present inhabitants and to attract others as well.

Exeter.

Exeter is one of the larger towns in the State with 56.10 square miles of land. [illegible] heavily wooded town with 86 percent of its land in fore[illegible] Arcadia State Park and Beach Pond State Park. Exeter [illegible] population of 3,245 and a population density of [illegible] per square mile. The town's population [illegible] by [illegible] in the past 20 years.

There is no industrial land and very little commercial land in Exeter. All of the commercial land is highway commercial. Only 2 percent of Exeter is re[illegible] giving it the lowest percentage of residential land in the state.

Nine percent [illegible] in agricultural use and more than one-half of that is tilled. Since a large part of Exeter's 86 percent forest is publicly owned, it will always be a heavily forested town. Only 2 percent of the town is in open water or wetland but 97 percent of its total area is in forest, farm and wetland.

Foster

Foster is also a large town with 52.28 square miles of land, but it has the second lowest population density in the State with 50 persons per square mile.

Industrial and commercial land occupies less than one percent of the land area in Foster, and all of it is light industry and highway commercial land. Foster has only 2 percent of its area in residences and nearly all of that is light density residential. The largest type by far is clustered residences on farm and forestlands. Foster has one percent of its land in developed recreation and all of this is occupied by golf courses and golf driving ranges.

Farmland covers 8 percent of the town; most of this is pasture and abandoned field. With only 889 acres of tilled land, agriculture is not important in Foster. Foster is heavily forested with 86 percent of the town in this use. Three percent of Foster is open water or wetland. Ninety-seven percent of Foster is in farm, forest or wetland. In a State as heavily populated as Rhode Island, it is astonishing to find as much truly wild forestland as that located in the western part. All this western forest is located within 30 miles of Greater Providence, one of the largest industrial and commecial complexes on the east coast

Glocester

Glocester is a town much like Foster in every respect. Glocester is large with 53.58 square miles of land. The population was 5,160 and the population density is 96 persons per square mile. Population in Foster increased 61 percent in the past 20 years while Glocester's population increased by [illegible] percent but with so low a population base to begin with, neither town is growing very fast. Less than one percent of the town is in industrial or commercial use and, like neighboring Foster, Glocester has no heavy industry. Only 4 percent of the town is in residential land and most of it is in medium and light density types.

Agricultural land occupies 7 percent of Glocester, including 266 acres of productive orchards. Eighty-four percent of the town is forested; only three towns in the State have a higher proportion of forest. Four percent of the town is open water and one percent is wetlands, so that 96 percent of the town is forest, farm or wetlands. Unfortunately, the acreage of farmland in both Foster and Glocester is rapidly declining as evidenced by the amount of abandoned field in both towns. Both towns need to do everything

they can to encourage the farmers to stay on the land because the scenic quality and wildlife production capacity of both towns depend heavily on the small amount of farmland present.

Johnston

Johnston is located on the fringe of the Greater Providence area. It has 24.31 square miles of land. The population was 22,037 persons and the population density is 906 persons per square mile. Population in Johnston has increased by 84 percent in the past 20 years. It is an urban town which serves in part as a bedroom community for the Greater Providence area. Johnston is very similar to Lincoln in this and many other respects. Two percent of Johnston is developed for industrial and commercial use; one-third of this land is industrial land and 38 percent of that is in heavy industry. Most of the commercial land is highway commercial land.

Residences occupy 16 percent of the town's area while the county averages 14 percent and the State averages 13 percent in this use. Twenty-six percent of the residential land is the old-fashioned, high density type with 50 feet of street frontage. Forty-one percent is of medium density with houses on one-quarter and one-half acre lots and most of the rest of it is clustered residential land in farm and forested areas.

Nine percent of Johnston is in agriculture with less than one-half of it in intensive agriculture including tilled land, orchard and [illegible]. Sixty-one percent of the town is forested and 7 percent is open water or wetlands. Two percent is in mining or waste disposal areas and most of that is sand or gravel banks. No other town in the State has as much automobile dumps. The 64 acres in this use account for one-quarter of all the automobile dumps in Providence County.

Providence

Located at the hub of satellite industrial and commercial cities, Providence is the most populous city in the State. The city had a 1970 population of 179,213 persons and a population density of 9,38[illegible] persons per square mile. Providence lost 17 percent of its population from 1950 to 1960 and 8 percent from 1960 to 1970 for a total loss of 28 percent for the two decades. An analysis of current land use in Providence may give some insight into the reasons for the population losses.

With only 19.10 square miles of land, Providence still has more heavy industry than any other city in the State. Eighteen percent of its land is either industrial or commercial and 29 percent of that is in heavy industry. Light industry occupies 218 acres.

Urban core commercial land occupies 1,125 acres in Providence and this accounts for 35 percent of all of this type in the State.

Residential land covers 44 percent of the city and nearly all of it is in high density types like garden apartments, tenements or town houses and high density houses on lots with 50 feet of frontage. Mining and waste disposal occupy very little area in the city while outdoor recreation covers 5 percent of the land area. Golf courses, athletic fields and urban parks account for most of the recreation land. Cemeteries are much used in urban areas for recreational purposes, and Providence, with 275 acres of cemeteries, has more cemetery space than urban park space. Transportation land covers 10 percent of the city area; water transport facilities and superhighways make up most of the transportation type. Urban open, urban public land, and cemeteries occupy 12 percent of the city.

One percent of Providence is in agriculture, 4 percent of it is in forest, and 6 percent of it is in open water. Most of this open water lies in the Seekonk River above the Interstate I95 bridge. In this city there is not much open green space; agriculture and forestland together only make up 5 percent of the city. Outdoor recreation adds another 5 percent of open space but much of this is athletic fields. The lack of green space and the 28 percent loss in population in the past 20 years may well be related.

Scituate

Scituate is a very large town with 55.06 square miles of land, a population of 7,489 and a population density of 136 persons per square mile. Population growth has been 92 percent in the past 20 years.

Less than one percent of the town is in industrial or commercial use and only 6 percent is residential. The majority of housing is medium and light density in keeping with the low population density of the town. Only 6 percent of the town is in agriculture, but 75 percent is forested. Twelve percent of the town is open water in the form of the Scituate Reservoir. Ninety-three percent of the town is in open green space and open water, and it is likely to remain so because of the extensive reservoir land holdings in the town.

Warwick

Warwick, a city of 83,694 persons in 1970, is the second largest city in the State but it is still less than one-half as large as Providence. With 2,264 persons per square mile, it is eleventh in population density among the 39 towns and it is growing rapidly.

The population in Warwick has increased by [illegible] percent in the past 20 years.

Warwick has 5 percent of its land in industrial and commercial development. Twenty-seven percent of this is industrial development, but only one-fifth of it is heavy industry. Most of the commercial land is highway commercial and shopping center. Warwick has considerable industrial and commercial development but little of it is unsightly heavy industry and little of the commercial land is urban core commercial. Thirty-eight percent of the town's land is in residential development. This is the largest percentage of any town in the county. Forty-four percent of the residential land is the high density type on lots with 50 feet of street or ocean frontage. This old-fashioned type occurs in the older parts of cities and as cottages on the ocean. Forty-four percent is of medium density with one-quarter and one-half acre lots while the other 12 percent is spread over all the light density types. Four percent of the town is in outdoor recreation. The largest type is golf courses, but there are saltwater beaches, marinas, playgrounds, athletic fields, amusement parks and urban parks. Warwick has abundant outdoor recreation developments.

Agricultural land occupies 9 percent of Warwick's area; 3 percent is tilled field while 6 percent is in abandoned fields and pastures. From a scenic point of view, the city will be more pleasant in the years ahead if the farmers are kept on the land and [illegible] areas are not allowed to grow up into forests. Twenty-eight percent of Warwick is presently forested, considerably below the statewide figure of 59 percent. Six percent of the city land is in open water, 3 percent in freshwater wetland and one percent in saltwater wetland. The agricultural land, forest and wetland should be carefully conserved as open space for its scenic quality and [illegible] wildlife.

West Greenwich

West Greenwich has 51.35 square miles of land. It has the second lowest population of any town in the State with 1,841 inhabitants and with 36 persons per square mile, it has the lowest population [illegible] in the State.

The town has only [illegible] acres in industrial and commercial development and only 2 percent of the land is in residences. Only Foster and [illegible] have as small a percent of the town area in residential land. West Greenwich has 400 acres in mining and waste disposal land and [illegible] percent of that is gravel banks. There are 22 acres in dump and 55 acres in automobile dump.

[illegible] percent of the town area is [illegible] agricultural land and 40

percent of that is tilled. The town had a larger proportion of its area in forest than any other town in the State--88 percent.

West Warwick

West Warwick is very small in area with 8.21 square miles but its total population of 24,323 is fairly large and its population density of 2,963 is the eighth highest in the State. West Warwick's population has increased by 27 percent in the past 20 years.

Seven percent of the town's area is in industrial and commercial development, the highest proportion for any town in Kent County, and 153 acres of this is heavy industry. West Warwick has 36 percent of the town area in residential land and one-third of that is high density residential land with houses on lots with 50 feet of frontage. A little more than one-half of the residential land is of medium density while the rest is spread over the light density types. Only 0.6 percent of the town is in mining and waste disposal but 15 acres of it is in automobile dumps. Only 2.7 percent of its area consists of developed outdoor recreation and golf courses compose most of this.

For a town with a relatively high population density, there is a high percentage of the land in agriculture (13 percent). Only 2 percent of the town is tilled while the remainder of the agricultural land is pasture and abandoned field. The percentage of land in agriculture is the same as for the State as a whole, but the total amount is small because the town area is small.

Thirty-one percent of the town is in forest, 3 percent is water and one percent freshwater wetland. Including agricultural lands, forest and wetland, West Warwick is nearly one-half open green space; for a town with a population density of 2,963 persons per square mile, that is a large percentage.

OTHER RELATED PROBLEMS AND NEEDS

This section presents other problems and needs that may possibly be interrelated with the flood management program of the Pawtuxet River Basin. Such an assessment has been made of the most pressing problems and needs, which are briefly identified.

WATER QUALITY

Present quality of significant portions of the Pawtuxet River Basin precludes or impairs the use of basin waters for many purposes

including recreation, fish and wildlife habitat, public water supply and aesthetic enjoyment.

Water quality in the watershed is varied. The upper reaches of the North and South Branches are Class "A" water whereas the lower reaches of the main stem Pawtuxet River are designated as Class "C" water.

Other than Cranston, Warwick and West Warwick, most of the watershed remains unsewered. Expansion of sewage treatment facilities in Cranston and West Warwick to handle an average of 11.5 and 5.0 mgd, respectively, have been completed. In Warwick where only about 20 percent of the city population is served, the city's sewage treatment plant of 5.0 mgd average has yet to achieve full design capacity. When all anticipated sewers are placed into service, additional treatment capacity will be needed. In general, most industrial firms in the basin have installed their own treatment plants or have tied into existing sewage treatment facilities.

Despite the expansion of treatment plants and elimination of discharges, the water quality on the Pawtuxet River and the lower reaches of its tributaries remains basically the same as it was a decade ago. A regional study of this problem was recently completed by the State. Under the increasing pressures of population growth and industrial expansion, abatement of pollution and the control of its effects must receive continuing evaluation. Under these pressures, planned facilities will need to be enlarged and controls above basic secondary treatment levels will require consideration. For unsewered areas particularly the western portion of the basin, sewage treatment facilities will have to be constructed if the pollution load of the basin is to be reduced.

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Although by land area the basin constitutes only 20 percent of the State, it supplies over 60 percent of its water supply. This is equivalent to about 75 MGD of the 115 MGD total and primarily drawn from Scituate Reservoir with the remaining yield being supplied from various other sources. For this reason it is the most important river system in the State, although it is the third in order of size.

The quality of the present water supplies in the Pawtuxet River Basin is good. The facilities have been adequate to meet the present imposed demands but new water sources to meet future needs are limited. The forecasts of future demands for public water in the State has been growing steadily and is expected to continue growing in the foreseeable future. As the State population grows,

increased demand for municipal and industrial water supplies can be expected.

In order to meet the anticipated future municipal and industrial water demands of Providence and surrounding communities, additional water supply sources should be developed. A principal source of additional supply is the proposed Big River Reservoir complex which would be constructed on the headwaters of the South Branch of the Pawtuxet River. Runoff from the Big River watershed coupled with diversions from Flat River Reservoir by flood skimming methods would develop an additional safe dependable yield of 42 MGD.

This additional source in combination with the existing Scituate Reservoir would produce a total safe dependable yield of 119 MGD which is adequate to meet future average daily water needs through the year 2020. The proposed Big River Reservoir would be developed by initially constructing the reservoir and dam, water treatment facilities and aqueduct to satisfy requirements expected by 1995. Expansion of initial facilities would be undertaken to meet average daily water demand of about 233 MGD projected for the year 2020.

A complete discussion of the water supply needs of the Providence metropolitan area is presented in the Interim Report of the Big River Reservoir project to which this report is attached.

OUTDOOR RECREATION

The Pawtuxet River watershed's water and related land resources are extremely valuable for recreation. Among existing and potential recreational resources are 6,000 acres of publicly or semi-publicly owned land and water, including John Curran and Snake Den State Parks, located, respectively, in Cranton and Johnston; 80 lakes and ponds with minimal beach development; and about 150,000 acres of wetlands, forests and water bodies, several thousand of which are protected for public water supply. The Bureau of Outdoor Recreation (BOR) estimates that the amount of publicly accessible and developed recreational resources is enough to satisfy six percent of the 1990 need for swimming, 60 percent of the 1990 need for campsites and two percent of the 1990 need for passive outdoor recreation. The deficiencies indicate a need to develop about 60 additional picnic tables, and about 15,000 additional acres of land for passive outdoor recreation.

The development of various recreation activities for the proposed Big River Reservoir have been carefully prepared to maximize the use and protection of unique features, and to minimize any impact on the water quality of the reservoir. This can be achieved in part by placing intensive recreation use activities, such as swimming and boating, outside of the public water supply watershed.

A possible recreation area for the Big River site, located near the east shore of the impoundment, would serve as an activity center for picnicking, shoreline fishing, and access to a multi-purpose trail system which could be used by hikers, horseback riders, and cross country skiers. The height of land in this location could offer scenic views of the west of the Big River Reservoir. In addition, parking facilities south of the reservoir would be available only during the hunting season. This would allow better control of access to the Big River site during the rest of the year.

LOW FLOW AUGMENTATION

Flows in the Pawtuxet River Basin are affected by both natural and man-caused regulation. In the first instance, natural flows vary seasonally, with high flows generally occurring from March to May, and low flows between July and September. Man-caused regulation is more typically daily and hourly in character and usually from the operation of upstream impoundments along the tributary streams.

Most of the basin impoundments, whether large or small, are currently used for water supply, industrial processing water and recreational purposes. With these impoundments acting to fulfill these needs, high river flows are generally regulated to maintain a stable pool at maximum level with flow releases being minimal but sufficient to satisfy downstream water rights as stipulated by agreement or law. These flow releases are generally made on a daily basis -- Monday through Friday -- with weekend releases being nil.

The gravity and extent of this problem is such that deficient low flows impair the basin's waters for many legitimate purposes.

Supplemental low flows could improve stream conditions to satisfy many resource needs. They could allow for more widespread recreational use of the rivers owing to increase quantities of flow; improve and stabilize fish and wildlife habitat for all aquatic species, provide for more constant year-round flows thereby stabilizing the natural channels and decreasing the erosion; and improve the overall health aspects, as well as increase the aesthetic enjoyment. Augmentation flows could come from new storages that would hold spring freshets for later released and have the multiple purpose effect of lessening flood problems proportionately. Additional flow augmentation could also come from re-regulation of existing storages.

FISH AND WILDLIFE

There is a need to solve several problems presencly facing the fish and wildlife resources of the basin. Significant among these are:

- Lack of public access
- Pollution
- Points of extreme low flow
- Single purpose use of the basin's ponded water supply areas
- Barriers to fish passage
- Insufficient amounts of fishing habitat in reasonable proximity to population centers
- Destruction or alteration of wildlife habitat

To satisfy the fish and wildlife resource needs of an expanding urbanized area, adequate controls to protect and enhance the existing resources will depend largely on the use that can be made of existing resources by providing high quality water, improvement of facilities, provision for more public access and supplementation of flows.

FUTURE CONDITIONS

FUTURE DEVELOPMENT

State planning officials have projected sizeable population increases by 1990 within the inner ring suburban communities of in Johnston, Cranston and Warwick, and a small increase in West Warwick. Most of this growth can be expected to occur in the western two thirds of Johnston, the western half of Cranston, the western third of Warwick, and to a lesser degree, the southern third of West Warwick. Substantial population increases can also be expected in the outer ring of suburban communities, especially Coventry in view of the ready availability of I-95. Possible extension of RI P-37 through southwestern Cranston may encourage additional growth in the Coventry-Scituate area. Future modification of U.S. 6 or possible redevelopment as I-84 could encourage growth in the now rural northern basin communities. Table 1-11 shows projected average annual population growth rates for all of the basin communities through 2020. Annual growth rates are generally higher in the outer ring of suburban communities because they are mostly small rural communities at the present time.

Recent construction of regional shopping facilities in Warwick should diminish the need for early construction of major shopping facilities in the Cranston-Warwick-West Warwick area. As

TABLE 1-11

POPULATION GROWTH RATES
AVERAGE ANNUAL GROWTH

Community	1970 Pop.	1950-1970 (%)	1970-1990 (%)	1970-2020 (%)
Providence	179,116	-1.6	0.2	0.2
Warwick	83,639	3.4	1.2	0.9
Cranston	74,287	1.5	0.8	0.7
West Warwick	24,323	1.3	0.8	0.7
Coventry	22,947	4.4	1.7	1.2
Johnston	22,037	2.8	1.7	1.1
Scituate	7,489	3.4	1.0	1.0
Glocester	5,160	3.4	1.7	1.3
Exeter	3,245	2.7	2.1	1.6
Foster	2,626	2.4	1.9	1.7
West Greenwich	1,841	3.9	2.9	2.0
Rhode Island	949,723	1.0	0.3	0.7
United States	--	1.6	0.9	0.75

population growth continues within the basin, the construction of additional commercial facilities may be expected in the areas such as in the vicinity of Coventry Center, North Scituate or the northern or western sectors of Johnston, for instance.

STATUS OF EXISTING PLANS AND IMPROVEMENTS

As covered in Appendix 2, two flood control projects, namely, "Clyde Levee" and "Pontiac Channel Diversion" were previously authorized but due to lack of local assurances in cost sharing requirements, they were de-authorized in 1951. Under the emergency authority of PL 84-99, two sections of dikes were constructed in 1970 for reducing flood losses against minor flooding in the community of Norwood in Warwick.

Pawtuxet Cove which lies at the mouth of the Pawtuxet River was authorized by the 1962 River and Harbor Act and completed in 1966. Located in Warwick, it serves as a base for navigational-recreational boating interest. Another project serving the same needs of the area is Apponaug Cove authorized by the 1962 River and Harbor Act and completed in 1966. Although the cove lies outside the boundary limits of the Pawtuxet River watershed, it would be impacted upon by the various alternative plans included in this report, therefore, it is considered to be an adjunct to this report.

Other than those stated plans, improvements and programs, there is no other Federally oriented project involvement in the Pawtuxet River watershed.

IMPROVEMENTS DESIRED

Industrial parks have been developed and partially occupied in the following areas: northeastern Warwick (Warwick Industrial Park near the river mouth), southwestern Providence along Mashapaug Pond, south-central Cranston (surplus portion of Howard State Institutions area), west-central Warwick near the State airport, and southeastern West Warwick near I-95. Other industrial parks are being planned in Johnston, Cranston and Warwick. Additional sites have been identified for consideration in other communities.

All communities have developed master plans for guiding future development. Adherence to such plans should permit the orderly provision of public services, as warranted, and assist in reducing urban sprawl through orderly planning.

FUTURE LOSSES DUE TO GROWTH

Future flood losses resulting from new growth in the flood plain are defined as damages to new economic activities which are expected to use the flood plain in the future (after 1972 when damage survey was completed) in the absence of a flood control plan. These new economic activities may include additions or enlargements to existing economic activities. Together with the increased discharge expected in the future, the total losses due to the anticipated economic growth were evaluated. To arrive at the final flood losses due to growth, basic relationships were established between damages, flood characteristics and those indicators used for measurement of growth.

Future losses due to growth are a function of the number of potentially vulnerable units of property expected to be added in the flood plain. The process used to measure future flood losses consisted of two primary elements, projection of the number and size of these physical units, and calculation of potential flood damages to them.

To estimate the units to be built by 1990 the Corps first evaluated historical land use in the flood plain and the immediate impacted area - primarily the cities of Cranston, Warwick, West Warwick and the town of Coventry. The town of Johnston and the city of Providence were omitted from the impacted area analysis. Johnston lies mainly in the Pocasset River watershed which has a comparatively small flood plain. The "Affected Area Land Use", Plate [illegible], shows the result of the historical land use analysis. The area comprising this analysis is limited to the main stem of the Pawtuxet River.

An approximate 100-year flood plain was delineated; SPF determinations were deemed unnecessary. As most of the new growth along the Pocasset has been residential and most of the available land is zoned as residential, any property added to this land use classification would be limited to the area between the 100-year and the SPF flood plain. It was then assumed that any future potential losses would be limited to nuisance type damages and that no long range flood control problems would develop. That portion of Providence within the Pawtuxet River Basin drains mainly into Roger Williams Park. As the drainage area is negligible, appreciable differences between normal water surfaces and those to be expected under SPF conditions is slight and any future flood control problems there would also be minimal.

With completion of land use assessment, future land use demands were then projected. Projections were made for 1990, a date conforming to published OBERS statistics, and the year 2040.

TABLE 1-12
AFFECTED AREA LAND USE [1]
1970
(Acres)

	TOTAL LAND			FLOOD PLAIN [2]			
	Current Use	Vacant	Total	Current Use	Available Vacant	Flood-way Vacant	Total
Residential	18,029	52,676	70,705	369	253	30	652
Commercial	1,830	1,240	3,070	203	29	24	256
Industrial	2,042	2,754	4,796	260	474	131	865
Recreation	178	115	293	--	--	--	--
Agriculture	587	--	587	--	--	--	--
Public	3,154	--	3,154	167	3	--	170
Airport	975	--	975	--	--	--	--
Open Space	100	--	100	3	--	--	3
	26,895	56,785	83,680	1,002	759	185	1,946

1) Affected area includes Cranston, Warwick, West Warwick and Coventry.

2) Includes area up to the SPF along main stem Pawtuxet River only.

[illegible] of the latter [illegible] chosen [illegible] the end of the planning period for projections [illegible] e with ER 1105-2-351, "Evaluation of Beneficial Contributions to National Economic Development for Flood Plain Management Plans." Projections of [illegible] graphic and economic activity within the affected area were made independent of any plan for flood control. Indicators used [illegible] of growth were population, housing units and industrial and commercial sector employment. These projections were converted to land use demand in the benchmark years utilizing indicator/land use ratios derived from historical data. Expressed on an annual rate basis, (acres/year) land use demand in Pawtuxet River flood plain is shown as follows:

	1970-1990	1990-2040
Residential	3.8	[illegible].0
Commercial	5.1	[illegible]1
Industrial	[illegible].0	[illegible].9

Although these figures are representative of land needed or demanded for development in the flood plain, constraints on land supply prevent total absorption. The most important constraint is adherence to the Flood Disaster Protection Act of 1973 (P.L. 93-234) as required by ER 1105-2-351. Coventry, West Warwick, Warwick and Cranston now operate under the regular flood insurance program and have had their land use regulations certified by the Flood Insurance Administration under 24 CFR 1910.3 (c) and/or (d) and 24 CFR 1910.5. Therefore, the "without-the-project" conditions are developed pursuant to the flood insurance regulations.

Under the "without-the-project" conditions combining the land use data and [illegible] the increased discharge relationships known, the figures [illegible] represents the losses to be expected to occur due to [illegible] growth. It should be noted that development of the comm[illegible] land available will occur rapidly. The year 1985 is chosen as the anticipated date that any project could become operative and much of the industrial and commercial growth has already occurred by 197[illegible]. The elevations at which the first floor slabs were laid are lower than the 100 year level in some instances. There are numerous examples of this within the Warwick Industrial Park and in some [illegible]

Annual Damages Due to Growth[1]

	1972-1985	1985-2035[2]
Industrial Growth	285,200	438,900
Residential Growth	103,400	0
Commercial Growth	174,650	0

SUMMATION - Although the Pawtuxet River watershed has yet to be affected by a "high damage" type of flood, there is a tremendous potential for substantial monetary losses in the area.

[1] 1972 dollars - utilizing average annual equivalent growth method

[2] 1985 to 2035 damages are "without project conditions" at this stage of analysis

APPENDIX 2

FORMULATION, ASSESSMENT AND EVALUATION

OF

DETAILED PLANS

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FORMULATION AND EVALUATION CRITERIA

The selected plan must represent an acceptable and justified solution that best responds to the problems and needs of the area. Technical, economic and social criteria were applied in evaluating all the possible alternatives as well as any potential environmental degradation that could occur because of the project's implementation.

Abbreviated planning methods were used for determining the most viable alternatives. They are explained more fully in the following paragraphs of this section. It should be emphasized that for all alternatives considered supplemental planning criteria involving public acceptability, project completeness, its effectiveness, any possible irreversible effects, and the ease of maintenance and operation were used to refine the number of alternatives to a tolerable number without obviating the problems and needs of the study area.

Socio-economic data used in evaluating the benefits and costs of the various alternatives considered were derived from Corps investigations and other basic economic data published by other Federal and State agencies. Hydrologic and hydraulic data were obtained from Corps investigations. Environmental impact information was obtained from Corps studies and from water quality sampling investigations by the Federal Environmental Protection Agency.

ECONOMIC CRITERIA

General economic criteria applied in the evaluation of alternatives are summarized as follows:

a. Tangible benefits must exceed project economic costs.

b. Scope of development should provide maximum net benefits, however, intangible considerations, such as risk to lives and property, could result in a project size which is greater than that which would produce maximum net benefits.

c. There are no more economical means, evaluated on a comparable basis, for accomplishing the same purpose or purposes which would be precluded from development if the recommended plan were undertaken. This limitation refers only to alternative possibilities that would be physically displaced or economically precluded from development if the recommended plan were implemented.

The economic benefits were initially evaluated at 1972 prices and field conditions. As this analysis progressed, estimates were updated to reflect new price levels, with the intermediate phases of

the plan formulation reflecting January 1976 prices. An interest rate of 6-7/8 percent was applied during the plan formulation process, but present project justification is based on the then prevailing interest rate of 6-5/8 percent. All the final plans shown in appendix have been updated to reflect September 1978 price levels. All projects were assumed to have a 100-year life. The current interest rate of 7-1/8 percent was used for project justification in the economics appendix.

TECHNICAL CRITERIA

Technical criteria were adopted from appropriate engineering regulations, manuals, pamphlets and technical letters, and supplemented by engineering judgment and technical experience. Basically, the plan should be engineeringly feasible to implement, be complete within itself and require no additional future improvements and insure against significant worsening of any flood conditions. Where practical, the alternative measures considered for urban areas were formulated for the standard project flood, an appropriate level of protection for high dikes and floodwalls in urban areas. If the standard project flood protection plan is unjustified or only marginally justified, the level of protection may be reduced to yield a more economically feasible plan by utilizing alternative flood damage reduction measures. However, reductions in the level of protection below the standard project flood were to be avoided whenever possible.

ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Environmental and social criteria utilized in considering the Environmental Quality Objective, and the Social Well-Being and Regional Development accounts should include the following requirements of the Natonal Environmental Policy Act of 1969 (Public Law 91-190):

a. Analysis of the environmental impact of any proposed action.

b. Identification of any adverse environmental effects which could be avoided should the proposal be implemented.

c. Evaluation of alternatives to the proposed action.

d. Determination of the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity.

e. Accounting of any irreversible and irretrievable commitments of natural resources and biological systems which would be involved in the proposed action should it be implemented.

In order to attain the environmental objectives as specified in the Principles and Standards, the following factors should also be considered:

a. Management, protection, enhancement or creation of areas of natural beauty and human enjoyment.

b. Management, preservation or enhancement of especially valuable or outstanding archeological, historical, biological and geological resources and ecological systems.

c. Enhancement of quality aspects of water, land and air, while recognizing and planning for the need to harmonize conservation of the resources with the land use objectives of productivity for economic use and development.

d. Development and use objectives which minimize or preclude the possibility of undesirable and irreversible changes in the natural environment.

As mandated by Section 122 of the River and Harbor Act of 1970, adverse economic, social and environmental effects of proposed projects should also receive full consideration and will include the following:

a. Effects of air quality, noise levels and water pollution.

b. Destruction or disruption of manmade and natural resources, aesthetic values, community cohesion, and the availability of public facilities and services.

c. Adverse employment effects and tax and property value losses.

d. Injurious displacement of people and businesses.

e. Disruption of desirable community and regional growth.

f. Public acceptance of proposed improvements and ability and willingness to meet local cooperation requirements.

Social well-being factors are other desirable elements that should be included in the study and should include the following:

a. Possible loss of life and hazards to health and safety of the people with and without project conditions.

b. Preservation of pleasing aesthetic values and other desirable environmental effects, such as pleasing landscapes.

POTENTIAL MEASURES

These environmental and social factors form the basis for evaluating and formulating alternative measures for the study area. Greater in-depth coverage of these considerations is included in the Environmental Impact Statement attached to the main report.

In formulating alternative measures an array of regulatory and corrective measures as well as a No Action program were considered. These measures were compared against the base condition using the criteria of economic efficiency, environmental enhancement and social well-being and were evaluated as acting either independently or supplementing one another. These measures are listed in Table 2-1. Subsequent paragraphs briefly describe each measure and the rationale used during the screening processes. Detailed descriptions are provided in this section for those measures which passed the preliminary screening phase and were further evaluated.

NO ACTION PROGRAM

In the recent several decades significant development has occurred within the flood plains. Some additional limited flood plain land will be built on until the existing Federal, State and local regulations are fully enforced. The No Acton Program assumes that in the absence of any corrective Federal Program, local interests would elect to participate in the National Flood Insurance Program (FIP) and enforce its requirements of controlling the future growth within the flood plains.

TABLE 2-1

POTENTIAL MEASURES

NO ACTION PROGRAM
(See Text for Definition)

REGULATORY MEASURES

1. National Flood Insurance Program

2. Flood Plain Regulations
   a. Encroachment Lines
   b. Zoning
   c. Subdivision Regulations

3. Land Use Programs

4. Other Regulatory Measures
   a. Building Codes
   b. Urban Redevelopment
   c. Tax Adjustments
   d. Warning Signs
   e. Health and Fire Regulations
   f. Cleanup Campaign
   g. Flood Forecasting

CORRECTIVE MEASURES

1. Land Treatment Measures

2. Reservoirs

3. Walls and Dikes

4. Reservoir Management Programs

5. Hurricane Barriers

6. Stream Improvements
   a. Channel Modification
   b. Modification or Removal of Dams
   c. Diversion of Flood Flows

7. Floodproofing or Relocation

By declining to participate in the NFIP, communities become ineligible for any Federal funds to be expended within a floodprone development. As ownerships of existing properties in the flood plain are transferred, new homeowners desiring financing from any Federally insured lending institution must obtain flood insurance. According to law, if this necessary insurance coverage cannot be obtained, a mortgage could not be underwritten.

The No Action Program is a measure that already has been adopted by some of the basin communities. As soon as the remaining towns enter the regular program of the NFIP, the No Action Plan will be completed. This program, at a minimum, would allow the flood plain property owner or a tenant the opportunity to purchase subsidized insurance coverage to help protect against any economic losses that would occur as a result of a major flood event.

REGULATORY MEASURES

By themselves regulatory measures do not reduce, eliminate or prevent the threat of flooding. They regulate or discourage the use and development of the flood plains, lessening the threat of flood damage and possible loss of life. Several regulatory measures which are nonstructurally oriented and applicable to this watershed are described in the following paragraphs.

National Flood Insurance Program - This program was established under the Housing and Urban Development Act of 1968, expanded in the Flood Disaster Protection Act of 1973 and subsequently amended. It was specifically designed to provide limited amounts of flood insurance, previously unavailable from private insurers, to property owners by means of a Federal subsidy. In return for this subsidy, the Act requires that State and local governments adopt and enforce land use and control measures that will restrict future development in floodprone areas in order to avoid or reduce futher flood damages. These measures include flood plain zoning, careful siting and drainage preparations, special construction practices and building materials, special treatment of sewage disposal systems, and elevation of the first floor above the level of the 100-year flood. Flood insurance is available through local insurance agents only after a community applies and is declared eligible by the Flood Insurance Administration, U.S. Department of Housing and Urban Development (HUD).

Flood Plain Regulations - Several decades of flood plain regulatory experience at State and local levels, plus a substantial body of favorable court cases, attest to the important role flood plain regulations can play in preventing future increases in flood problems. Implementation of adequate regulations may prohibit new

uses in urban and rural floodway areas that may cause damaging increases in flood heights. They may require that new uses in both urban and rural flood areas be designed with individual flood protection through elevation on fill or structural floodproofing to the 100-year flood elevation.

There are three principal flood plain regulatory tools at the local level that are available for usage. These consist of zoning, subdivision controls and building codes. Each is detailed in the following paragraphs and summarized in Tables 2-2 through 2-4.

a. Zoning - Zoning is the most popular local flood plain management. Traditional zoning divides a community into districts and applies varying use standards to each of the districts. A zoning ordinance consists of a map which delineates the use districts and a written text that describes use standards for the districts. Use standards are of two types, one that determines the classes of use (commercial, residential, etc.) in the district and the second that establishes minimum standards for permitted uses, such as lot size and building setbacks.

Flood plain zoning maps and the accompanying text are often part of a broader zoning ordinance. One or more flood plain districts are usually delineated on the community zoning map. A single district approach tightly controls all development within the delineated areas. Its use is acceptable for rural towns where considerable vacant land exists in a nonflood plain area. A second approach involves the delineation of two districts; a floodway and flood fringe area. Development is tightly controlled in the floodway to preserve flood flow capacities, but a wide range of uses is generally permitted in the flood fringe as long as each individual structure is protected against flooding losses at the hundred year event. This two district approach permits a wider range of flood plain losses.

The floodway is a portion of the area a selected flood (100-year for the purposes of this report and to coincide with the NFIP definition) would occupy, consisting of a stream channel and overbank areas. The floodway is calculated to be capable of conveying the selected flood discharge without flood heights or velocities increasing to exceed stated levels (1-foot for this report and NFIP). The regulatory floodway is not an actual channel or concrete conduit, rather an area of sufficient width and flood conveyance characteristics to pass the flood waters from upstream to downstream points along a watercourse without increasing the flood heights. In this calculation all areas outside the floodway are assumed to play no role in passing flood flows, and the floodway itself is assumed to remain in an open condition. Floodway areas are subject to frequent high velocity flooding often at considerable depths. The flood fringe is the

TABLE 2-2

OVERVIEW: FLOOD PLAIN ZONING

Purposes	Regulatory Standards	Advantages	Limitations
1. Protect public safety and prevent nuisances by prohibiting dangerous uses (e.g., chemical factories in flood hazard areas), unreasonable increases in flood heights due to floodway encroachments, and threats to safety by location of quasi-public uses such as motels in flash-flood areas.	1. Delineate floodway areas and prohibit new structural uses and land alterations which will individually or cumulatively increase flood heights or velocities beyond defined levels.	1. The major tool of comprehensive planning to promote the most suitable use of lands throughout a community.	1. May "take" private property if too restrictive.
2. Promote most suitable and economic use of community lands as a whole by implementing comprehensive land use plans allocating flood plain areas to uses consistent with the flooding threat.	2. Establish flood protection elevations and protection standards for floodway and flood fringe areas and uses.	2. Can incorporate wide range of provisions relating to flood plain management and other objectives.	2. Does not regulate sale or transfer of lands.
3. Reduce the cost of public facilities and assist in the implementation of facility plans for roads, sewer, water, schools, etc. by preventing or limiting the type and density of development in flood hazard areas.	3. In some instances, abate existing floodway uses of a nuisance nature and require floodproofing with major alteration of flood fringe uses.	3. Can separate flood areas into zones depending upon flood hazard and apply varying standards to the zones.	3. Often weakened by irrational variances and exceptions.
	4. Divide flood fringe into commercial, residential and industrial flood fringe zones, and other districts with specifications designed to reduce conflicts between uses and promote the general welfare.	4. Most useful tool in preserving floodway areas.	4. Is largely prospective in nature (applies only to new uses) and usually unsuccessful when applied to high-value, nonnuisance existing uses.
		5. Can be applied (in some areas) to existing uses with a nuisance character.	5. Usually does not incorporate detailed building design standards.
			6. Many states require prior comprehensive, community-wide planning although this requirement has not been strictly enforced.

TABLE 2-3

OVERVIEW: *FLOOD PLAIN SUBDIVISION REGULATION*

Purposes	Regulatory Standards	Advantages	Limitations
1. Prevent victimization and fraud due *to sale of flood lands* to innocent purchaser.	1. Prevent subdivision of land *unsiutable for intended* purposes.	1. In many states, may be made to apply extra-terrirorially for urbanizing areas.	1. Only indirectly controls use of land; must be in combination with zoning.
2. Protect floodway *areas from* encroachment by *roads*, buildings, etc.	2. Require that each building site have an *area* above flood elevation *suitable for building purposes*, on-site waste disposal (where applicable) and adequate access.	2. Very flexible in negotiating with developer.	2.. Difficult to protect floodways unless they are identified on maps.
3. Insure that roads, sewers, water supply, and other subdivision services are located in areas above flood elevations or protected against flooding.	3. *Require that flood hazard areas* be noted on face of plat, and in some cases, the adoption of deed restrictions to control future uses *in flood-prone areas*.	3. In most states, does not require prior comprehensive planning although a street plan is often required.	3. Does not apply to structural design or materials for future structures on subdivision land.
4. Implement master and comprehensive plans including public facility components.	4. Require flood protection for sewer, water, and roads installed by subdivider.	4. *Can be used to require* developer to provide flood data on a case-by-case basis.	4. *Applies*, *in many instances*, only to new land sales and divisions.
5. Insure that subdivider installs drainage facilities which are consistent with community drainage system standards.	5. Require installation of drainage facilities or payment of fees in lieu of installation by subdivider.	5. Not as vulnerable to judicial attack as zoning.	5. "Loopholes" common in *ordinances* which permit subdividers to escape enforcement through "strawman" *transactions* (*i.e.*, *multiple divisions* through friends, relatives).
	6. In some instances, require dedication of flood areas as parks or for other open space purposes by the subdivider.		

TABLE 2-4

OVERVIEW: FLOOD PLAIN BUILDING CODES

Purposes	Regulatory Standards	Advantages	Limitations
1. Protect public and private safety from structures which may collapse during flood.	1. Require elevation of structures and utilities on fill, pilings, or by other means.	1. Applies to new structures.	1. Applies only to new uses.
2. Prevent nuisances from floating structures which may jam bridges, litter other lands, and add to the destructive force of flood flows.	2. Alternatively, require structural floodproofing of buildings and utilities through special design and use of waterproof materials.	2. Often sustained in court.	2. Performance standard approaches require expertise in administration
3. Protect public facilities.		3. Can be adopted by reference in most states.	3. Do not usually apply extra-terrirorially.
4. Prevent blighting, reduction in property values, decrease in tax revenues.		4. Simple adoption procedures.	4. Must be used in combination with other tools to preserve floodway.
5. Protect buildings and contents from flood damage.			5. Often not properly enforced.
			6. Detailed flood elevation data essential for operation of regulations. Flood velocities, flood duration, wave action, erosion problems and other types of "site specific" data required to design or evaluate proposals for structural flood-proofing.

portion of the regulatory flood plain beyond the limits of the floodway. It is subject to less frequent and lower velocity flooding and does not play a major role in passing flood flows. See Figure 2-1 for a graphical view of each definition.

b. Subdivision Regulations - Subdivision regulations control the division and sale of lands. the regulations require that landowners prepare detailed maps or "plates" prior to the sale of lots. Plates must first be approved by the planning commission. Plates must comply with standards established in the subdivision regulations, zoning and other laws. Subdivision standards relating to flooding typically require that lots be made suitable for these intended uses, and that the subdivider install public facilities such as roads, sewers and water with partial or total protection from flooding.

c. Building and Housing Codes - These simply regulate the building design and construction materials. Building areas and a variety of special codes have been adopted by some communities to reduce flood problems or assist in the construction of flood control works. Codes are subject to the same general legal requirements as zoning and subdivision control. They address limited aspects of flood plains use and a small number of uses and are therefore less susceptible to challenge than the taking of property. However, when exercised in isolation they are also less useful in carrying out overall flood plain management goals.

Flood Warning Systems - The National Weather Service (NWS) is responsible for forecasting flash floods (those which crest within a period of six hours) and major floods (those which take a longer period to crest). Flood warning systems utilize sirens, radio, television and newspapers to disseminate information on floods.

A few communities have adopted flash flood alarm systems which automatically activate an alarm when flood waters reach a certain level.

Of course, the determination of a flood hazard is only one aspect of a flood warning system. The other aspect--dissemination of information concerning the hazard--is often more difficult. Television and telephones have somewhat simplified the task, but serious communication problems still exist for sudden flood events.

To be optimally useful, flood warnings must allow sufficient time for the evacuation of the people and goods from the flood plains or the initiation of emergency flood protection measures. Flood gates and movable doors for floodproofing may be inoperable due to lack of maintenances or repair, or they may have been misplaced. Cars may not be able to be removed from dealer lots. Material or stock and

contents may not be able to be elevated to higher ground. It is therefore important that logistic support be provided to make use of advance warnings.

Urban Renewal - Urban renewal has been used in some instances to renovate, raze or rebuild some flood blighted areas and to allocate the lands to open space use to reduce flood losses, provide open space, reduce disease and serve other community objectives.

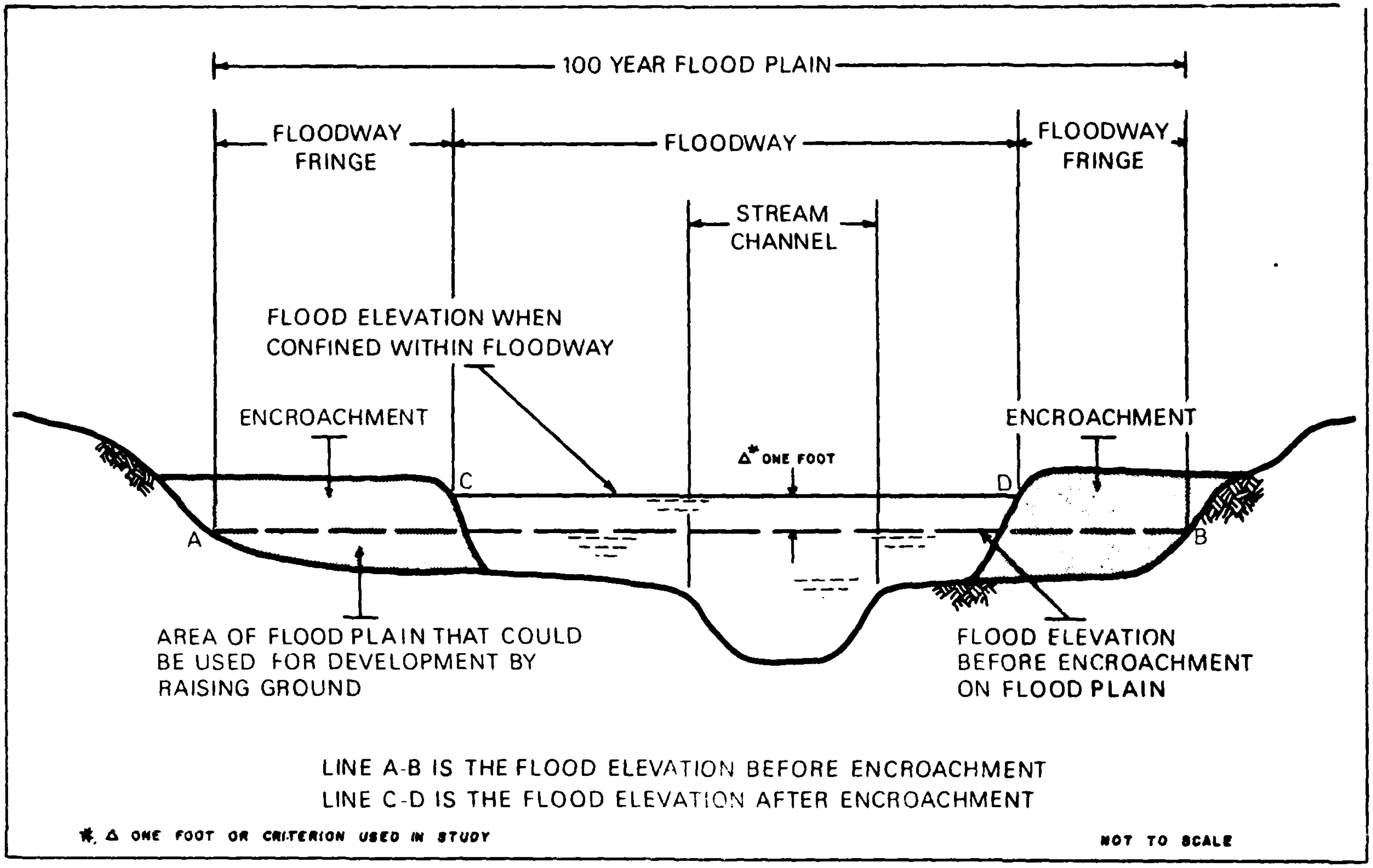
Tax Incentive - Tax incentives have, in some instances been used to encourage preservation of the flood plain in an open condition and to reduce flood losses, provide open space, preserve agricultural land and meet other objectives.

Public Open Space Acquisition - The acquisition of flood plain areas for public open space use has grown rapidly in popularity. Some cities such as Milwaukee have purchased virtually all flood plain areas for park and parkway use. Such acquisitions may serve the final functions of controlling private development and providing public open space for parks, wildlife areas, hiking, water sports and similar use. Public open space recreation uses often may be designed with minimum damage potential from flood waters.

While flood plain lands may be less costly for park acquisition than similar lands throughout a community due to the flooding threats, acquisition costs often exceed several thousand dollars per acre. For this reason, easement rather than fee purchase may be attractive. However, experience with scenic, conservation and similar types of easements may sometimes be expensive and are unsatisfactory where the public must make intensive use of private land for picnicking or other uses.

Federal grants in aid for park acquisition are available from the Land and Water Conservation Fund of the Bureau of Outdoor Recreation. In addition, revenue sharing and State open space funding programs are available im many states. Generally, the total Federal share may not exceed fifty percent of acquisition costs although State grants-in-aid may increase the total State and Federal contribution. In some states, park acquisition for flood plain lands is given high priority because of the multiple benefits involved. However, flood plains do not in all instances make good parks because of their topographic features or inaccessability to users.

Proposals have been made to subsidize local flood plain acquisition for open space purposes through State or Federal grant-in-aid. Such Federal or State subsidies to accomplish multiple goals might in some instances be favored in comparison with flood control works because of the multiple benefits (recreation, flood loss reduction) accrued.



DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

FLOODWAY SCHEMATIC

Figure 2-1

CORRECTIVE MEASURES

In urbanized flood prone areas, the most cost effective way to reduce existing flood losses is with corrective measures. When considering several flood prone city blocks of stores and homes, or a large industrial center, it is unrealistic to expect that the regulatory measures will suffice in reducing flood problems.

These corrective measures listed below are the traditional measures that deal with flood problems. These modifications of the natural flood regime are designed to change the extent and timing of flood flow to lower elevations and to partially or wholly protect individual structures or entire areas from flooding. Each technique has a somewhat different function and application.

Land Treatment Measures - Substantial portions of the upper watershed have undergone a land use change from agriculture to residential or other urban types. As this practice is expected to continue, vegetative and mechanical land treatment measures could be an effective tool in helping to control erosion. In addition to damaging the lands from which the soil originally came, erosion greatly increases the sediment transport rate of the stream resulting in high deposition and increased scour rates. It is therefore necessary to try to control erosion in these developing areas. Proper grading of the new subdivisions along with the preservation of as many trees and shrubs as possible is essential. Where feasible, fast growing annual grass seed should be used interspersed with the slow growing perennial species, to help establish a good soil cover. Maximum slope grading should be established which would slow down any runoff and subsequent scour.

Significant areas of land are still farmed. To help retard the erosion rate conservation land treatment practices should be practiced. Some of these measures are contour farming, cover cropping, terracing, critical area planting, pasture and hayland management and stabilization.

If the above practices are not possible either in the urban or rural areas, alternative measures should be employed to help reduce the erosion. Some of these measures are debris and desilting basins, mulching of steep slope areas, or the establishment of planted buffer zones between open areas.

Reservoirs - These are designed to temporarily hold floodwaters and release them slowly to reduce flood peaks. In New England these generally consist of rolled earth and rockfilled structures for impounding uncontrolled floodwaters. They are generally located at

strategic points within a watershed to provide flood protection to downstream communities. An important factor relating to reservoirs that should not be overlooked is their ability to satisfy other needs. Such multiple objectives result in greater utilization of the available natural resources within a watershed.

Walls and Dikes - This approach usually involves a system or a combination of concrete floodwalls, earth-rockfilled dikes and appurtenant facilities for confining flood flows to the channel or floodway. These are generally referenced as local protection projects because they provide protection to localized, high risk flood prone areas located behind the dike system.

Reservoir Management Programs - The objective of this approach is to temporarily retard peak flows long enough to desynchronize tributary flows from the flood peaks on the main stem or at high damage areas. The water stored in the reservoir is then released at a controlled rate as soon as possible after the flood peak. To be effective considerable dependable storage must be available at all times during the year and a means of controlling the upstream runoff and reservoir releases must be present. There are no such existing sites in the Pawtuxet Basin. If any future reservoir is constructed some form of control structure and dependable storage for flood control should be considered.

Hurricane Barriers - This measure is utilized where low lying heavily urbanized areas are exposed to either hurricanes or storm induced tidal surges. They consist of a system of dikes and walls along low lying lands that are tied into a rockfilled jetty that also usually contains navigational gates and a pump house. When the barrier is placed into operation, the navigational gates (and street gates if any) are closed and braced and the pumps activated. These pumps are used to prevent an increase in the water surface behind the protection caused by any tributary drainage that now cannot flow out normally to the sea.

Stream Improvements - Where substantial flood damages can be attributed to the deterioration or neglect of the waterways, a rehabilitation program for improving channel conditions to increase their hydraulic efficiency and subsequent flood carrying capacity could generally be accomplished by the following measures:

a. To alleviate frequent flooding and subsequent flood losses various methods of channel restoration work could include:

-Possible elimination of abrupt turns and oxbows;

-Widening and deepening of certain stretches of river;

-Improvement of waterway areas at bridges and culverts;

-Removal of shoals, sandbars and islands impeding minor flood flows; and

-Removal of overhanging trees, uprooted trees and accumulated debris at critical points.

b. Channel improvements of restricted pondage areas by modification or removal of dams could also offer some flood relief to critically high risk flood prone areas providing proper measures are taken to prevent excessive scour siltation.

c. The diversion of flood flows as a means of bypassing heavily congested flood prone areas could provide an adequate and high degree of flood protection while minimizing the social and environmental impact.

CORRECTIVE NONSTRUCTURAL METHODS

Temporary and Permanent Closures for Openings in Existing Structures - Structures whose exterior is generally impermeable to water can be made to keep floodwater out by installing watertight closures in openings such as doorways and windows. While some seepage will probably always occur, it can be reduced by applying a sealant to the walls and floors and by providing a floor drain where practical. Closures may be temporary or permanent. Temporary closures are installed only during a flood threat and therefore need warning time for installation.

As most residential structures in this area are made of wood frame construction only the basement would be considered applicable for floodproofing. However, as many industrial and commercial establishments are constructed of concrete block with relatively few openings at zero to three feet above the first floor slab, serious consideration should be given to protecting them, even if at their owners expense. There are several disadvantages to this means of protection. As mentioned above, it is applicable only to structures with brick or masonry type walls, and only to a level where they can withstand the hydrostatic and uplift pressure of the floodwaters. Another disadvantage is the reduced likelihood of effective closure at nights and during vacations when temporary closures are employed; and lastly the entire measure may create a false sense of security and induce people to stay in the structure longer than they should.

Raising Existing Structures - Existing structures in flood hazard areas can often be raised in place to a higher elevation to reduce the susceptibility of the structure to flood damage. Specific actions required to raise a structure include:

a. Disconnect all plumbing, wiring and utilities which cannot be raised with the structure.

b. Place steel beams and hydraulic jacks beneath the structure and raise to the desired elevation.

c. Extend existing foundation walls and piers or construct new foundation.

d. Lower the structure onto the extended or new foundation.

e. Adjust walls, steps, ramps, plumbing and utilities and regrade site as desired.

f. Reconnect all plumbing, wiring and utilities.

g. Insulate exposed floors to reduce heat loss and protect plumbing, wiring, utilities and insulation from possible water damage.

These actions are intended to place the structure at a higher elevation at its existing site and to protect plumbing and utilities previously below the first floor from water damage. Because the hazard is not eliminated, but only the damage potential reduced, it is important that the potential for flooding below the first floor be recognized in the raising. Lateral stability of the structure should be insured by designing the foundation walls. Such design would include the use of thick concrete mats for the floor slab and a structurally designed concrete wall. Both necessitate the use of reinforcing steel.

Some of the advantages to raising a structure are as follows: Damage to structure and contents is reduced for floods below the raised first floor elevation. It is particularly applicable to single and two story structures already on a raised foundation. There are no elevation limitations to raising a structure as long as the floodwaters are allowed to pass through the basement. Finally, the flood insurance premiums for the secondary layer of coverage are drastically reduced.

Some of the disadvantages are as follows: Residential damages exist when floods exceed the raised first floor elevation. Minor damage may occur below first floor depending upon use. Measure is not generally feasible for structures with slab on grade foundations or for complete floodproofing measures where cellar flooding is not tolerated. Extensive landscaping and terracing may be necessary if the height raised is extensive. Finally, that the costs are approximately 50 percent of the market value of a home, making it extremely difficult for the average homeowner to afford.

Small Walls or Dikes - This measure consists of a minimal height wall or dike, generally less than 6 feet and so designed that it protects one or several structures and is built to be compatible with local landscape and aesthetics. Walls may be of any suitable material and so designed that they resist the lateral and uplift pressures associated with flooding. Dikes are usually constructed with an impervious core to prevent seepage and with a slope protection if erosion is a problem, or both of the above where access openings are necessary. Provisions must be made to close these openings during floods. Interior drainage facilities such as a small sump pump may be necessary to control the land and roof runoff.

Rearranging or Protecting Damageable Property Within an Existing Structure - Within an existing structure or group of structures damageable property can often be placed in a less damageable location, or protected in place. It is something every property owner can do to one degree or another depending upon the type and location of the susceptible property and upon the severity of the flood hazard. Some of the possibilities are as follows:

a. Protecting furnaces, water heaters, air conditioners, washers, dryers, shop equipment and other similar property by raising them off the floor. This may be appropriate for shallow flooding conditions.

b. Relocating damageable property to higher floors. Moving property from the basement to the first floor or second floor would be an example. This action usually requires altering ducts, plumbing and electrical wiring and making space available at the new location.

c. Relocating commercial and industrial finished products, merchandise and equipment to a higher floor, or adjacent and higher building, or to a less flood prone site.

d. Anchoring all property which might be damaged by movement from floodwater.

Removal of Structures from the Flood Hazard Areas - The previous description discussed relocating and protecting damageable property within an existing structure. However, at a certain level, this is no longer feasible. This section discusses two options for removing property to a location outside the flood hazard area. One option is to remove both structure and contents to a flood free site. This involves:

a. Locating and purchasing land at a new site.

b. Preparing the new site, services, driveway, sidewalk and new foundation.

c. Raising structure off its existing foundation, transporting it to the new site and placing it on this new foundation.

d. Moving contents from existing to new location.

e. Removing, disposing and backfilling the foundation at the existing site.

f. Providing temporary lodging during relocation.

A second option is to remove only the contents to a structure located at a flood free site and demolish the existing site. This measure includes:

a. Locating an existing structure, or building a new structure at a flood free site.

b. Moving contents from an existing to a new location.

c. Either demolishing, and where possible salvaging the existing structure, or reusing it for a less damage susceptible use.

INITIAL SCREENING

Table 2-5 illustrates the initial screening and elimination process used in the first phase of formulating a flood management plan for the Pawtuxet River Basin. Utilizing available data concerning known flood problems within the basin and known desires of local interests, all potential solutions were evaluated and judged on their own merits at this stage of the analysis, with each measure acting independently. Only those measures that provided an adequate, realistic and practical engineering solution and would be socially acceptable, environmentally acceptable and economically justified were reserved for more detailed consideration in the intermediate screening.

At this stage of the evaluation analysis, the No Action program and regulatory measures were determined to be applicable to all 16 zones in the watershed. Both programs would be geared to preventing or minimizing flood losses to existing and/or future flood plain development, rather than providing reductions in flood stages. As such, they could supplement possible corrective measures, and both programs were reserved for subsequent evaluation.

CORRECTIVE MEASURES

The following corrective measures were analyzed as independent components for solving specific flood control problems and needs pertaining to the basin:

TABLE 2-5
INITIAL SCREENING

POTENTIAL MEASURES	1	1A	2	2A (2A-1+2)	3	4	4A
NO ACTION PROGRAM	E	E	E	E	E	E	E
REGULATORY MEASURES (ALL)	E	E	E	E	E	E	E
CORRECTIVE MEASURES							
Land Treatment Measures	5	5	E	5	5	4	4
Reservoirs	1	5	E	5	1, 2, 3	1, 2, 3	1
Walls & Dikes	5	1	5	1	5	E	1
Reservoir Management Program	E	4	E	4	4	5	4
Hurricane Barriers	6	6	6	6	6	6	6
Stream Improvements							
Removal of Dams	5	4	4	4	5	2	4
Diversion of Flood Flows	4	1	4	1	2	E	1, 2
Channel Modification	5	5	5	5	5	1, 3	1, 3
Flood Proofing or Relocation	5	E	5	E	5	E	5

CRITERIA APPLIED DURING SCREENING

1. Economically Infeasible
2. Engineeringly Impractical
3. Socially Unacceptable
4. Inadequate Solution
5. No Major Needs or Problems
6. Not Applicable

DAMAGE ZONES

North Branch --------- 1-1A
South Branch ---------- 2-2A
Main Stem------------ 3-8
Meshanticut Brook ---- 4A-4B
Pocasset River ------- 6A-6B
Roger Williams Brook - 7A-7B

ıBLE 2-5
ıL SCREENING

ZONES											
	4	4A	4B	5	6	6A	6B	7	7A	7B	8
	E	E	E	E	E	E	E	E	E	E	E
	E	E	E	E	E	E	E	E	E	E	E
	4	4	4	4	4	4	4	5	5	5	4
2, 3	1, 2, 3	1	1	1, 2, 3	1, 2, 3	1	1	1, 2, 3	5	2	1, 2, 3
	E	1	1	E	E	1	E	E	5	E	E
	5	4	4	4	4	1	4	4	1, 3	4	2
	6	6	6	1, 2, 3	1, 2, 3	6	1, 2, 3	1, 2, 3	6	1. 2, 3	1, 2, 3
	2	4	6	6	6	3, 4	6	6	3, 4	6	4
	E	1, 2	1, 4	2	2	1	1	2	1, 4	2	2
	1, 3	1, 3	1, 3	1	1	1, 3	1, 3	1, 3	5	1, 3	1, 3
	E	5	E	E	E	E	E	E	5	E	E

NES

------- 1-1A
------- 2-2A
------ 3-8
k ---- 4A-4B
------- 6A-6B
Brook - 7A-7B

LEGEND

E	Further Evaluation Warranted
#	Further Evaluation Unwarranted

Land Treatment Measures - Of the 16 zones in the watershed, only zone 2 has been considered for land treatment measures. This is due to the potential construction of Big River Reservoir and the need for soil erosion prevention during construction. In the other zones significant erosion and sediment problems were deemed nonexistent, not subject to correction by vegetative or slope protection measures, or have been aggravated mostly by recent uncontrolled urbanization which will eventually stabilize resulting in less critical erosion. Assistance in land treatment measures in certain zones is available, under existing authority, through the Soil Conservation Service, U.S. Department of Agriculture.

Reservoirs - Within the study area, numerous reservoir sites were originally investigated to alleviate flooding as well to satisfy other needs. Due to the limited degree of protection that small reservoirs could provide to existing damage areas, the many engineering, social and environmental constraints, and due to the findings that costs would far exceed accrued benefits, most of the reservoir sites considered were eliminated from further evaluation. Results of this preliminary analysis indicated, however, that 12 reservoir sites warranted further investigation, either as single purpose flood control projects or as multi-purpose projects.

Of these 12 reservoir sites, seven were within the Pocasset River watershed, namely: two each on Simmons and Dry Brooks and three on the main stem of the Pocasset River. Along Furnace Hill Brook, a tributary of the Meshanticut Brook, another reservoir site was evaluated. On both the North and South Branches, four impoundments were analyzed. Two involved modification of the existing Flat River and Scituate Reservoirs, the third involved provision of a sub-impoundment at Scituate Reservoir, and the fourth entailed evaluation of the Big River Reservoir site as a multiple purpose impoundment. Of this entire group, only one potential project was found to warrant further evaluation, the Big River Reservoir project that would provide substantial flood reduction benefits for Zone 2A. As this project is presently under the jurisdiction of the Rhode Island Water Resources Board and in the preliminary engineering design stage, it is essential that consideration be given to providing additional storage for flood control.

Modification of the existing Scituate Reservoir was found to be economically unjustified. The reach immediately downstream from Scituate Reservoir does not have significant flood problems and is adequately protected by the existing dam. To utilize Scituate Reservoir for flood control purposes would require raising the existing structure an additional 10 feet. This would serve only to reduce the required size of downstream structures, rather than

eliminate their need. It was determined that the cost of added storage at Scituate Reservoir would be greater than the cost of corresponding increases in the size of downstream projects. Therefore, such modification of Scituate Reservoir was unjustified.

Walls and Dikes - Concrete walls and dikes, generally referred to as local protection projects, were deemed to be an effective means for providing flood protection to high risk flood prone areas. Zones 4, 5, 6, 6B, 7, 7B and 8 meet these high risk conditions. As a result wall and dike measures were retained for further evaluation. The remaining damage zones were eliminated from further consideration since they are subject to only minimal flood losses.

Reservoir Management Program - The basic element in a reservoir management program entails lowering the levels of existing reservoirs to reduce peak flood discharges thereby reducing damages. With the exception of Scituate and Flat River Reservoirs, further investigation of other small reservoirs was deemed impractical due to the small storage capacities involved.

Hurricane Barriers - To eliminate the threat of tidal flooding, hurricane barriers were considered at two locations, one near the mouth of the Pawtuxet River and the other at the entrance to Pawtuxet Cove. Both projects would require substantial construction and river widening. Further consideration of both these projects was determined to be unwarranted due to high construction and relocation costs and adverse social and environmental impacts. The former would involve total reconstruction of the Pawtuxet Dam. It would consist of a control structure with a wall traversing the river, and a large pumping station. In order to allow for the passage of riverine flood flows, the existing channel would have to be widened to about twice its present size for a distance of about 4 miles, this would necessitate relocation of some of the existing highly flood prone industrial-commercial properties as well as significant portions of the Norwood residential area. Six bridges and many local roads will also have to be significantly modified.

The barrier at the entrance to Pawtuxet Cove would require a large rock jetty and navigational gates in addition to this control structure and pumping station. The widening of the lower portions of the Pawtuxet River would still be required. In addition to providing flood protection to the lower portions of the Pawtuxet, this scheme would provide protection to the large recreational navigation fleet residing in Pawtuxet Cove as well as low lying properties.

Further consideration of either or both of these projects was determined to be unwarranted due to the high construction costs, relocation costs and the adverse social and environmental impacts.

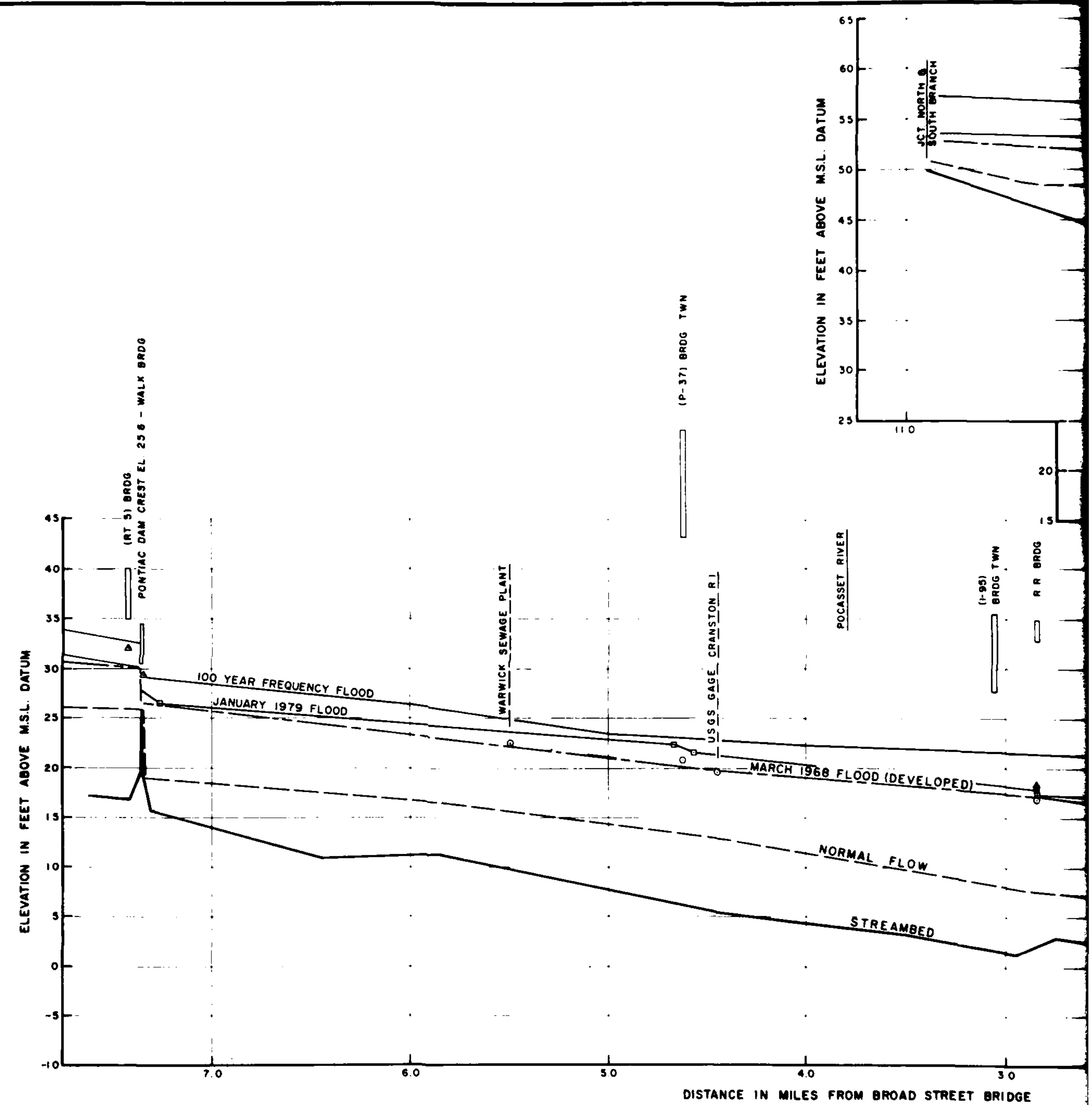
The annual benefits of such a proposal would be less than a million dollars where construction cost on an annual basis could be well over $4 million.

Stream Improvements - The channel conditions of some of the streams within the basin have been neglected to such a degree that their deterioration has affected their hydraulic efficiency. Some of the flooding condition has been aggravated either by siltation, riverbank and lowland encroachment, inadequate bridge and culvert openings or general neglect in the removal of excessive vegetative growth and accumulated debris, particularly more noticeable along the smaller tributaries such as Meshanticut Brook and the Pocasset River. Although relatively insignificant for a major flood these conditions can cause increased flood stages and more damages at a frequent type storm event. Removal of dams, diversion of flood flows and channel modification were considered as a means of remedying these conditions.

a. Removal of Dams - Within the basin there are numerous dams serving the needs of the area. Many of the smaller dams, originally intended for power generation and for process water, have not only been neglected but have become obsolete. Their siltation has caused restricted pondage and impedance to normal river flow.

As it has been suggested by concerned interests removal of some of these dams would reduce flood flow gradients, thereby reducing flood damages. The dam most often referenced was the Pawtuxet Dam situated at the mouth of the Pawtuxet River. This dam consists of a low head structure that prevents saline intrusion under normal tides. The riverbed slope upstream of the structure has a very flat hydraulic gradient resulting in a slow moving stream with subsequent very low velocities. Results of backwater studies performed to determine the effects of complete dam removal have indicated that during a standard project riverine flood, the flood stage would be reduced about 7 feet at the dam (see plate 2-1) with reduction diminished upstream and becoming insignificant at Warwick Avenue. For a 100-year flood event, flood stage reduction would average about 5.5 feet at the dam diminishing to nil at Warwick Avenue.

Removal of this dam would have the associated impacts of: (a) returning the lower Pawtuxet to a tidal estuary with a large degree of irretrievable environmental harm; (b) as normal riverflow velocities would be increased, bank erosion would become a problem, especially in areas now inundated by the dam's backwater. This would necessitate costly slope protection methods in such erosion prone areas; and (c) the sludge deposits behind this dam would become suspended either by natural effects or by dredging. Benthic studies in Pawtuxet Cove and other Pawtuxet River areas indicate that the



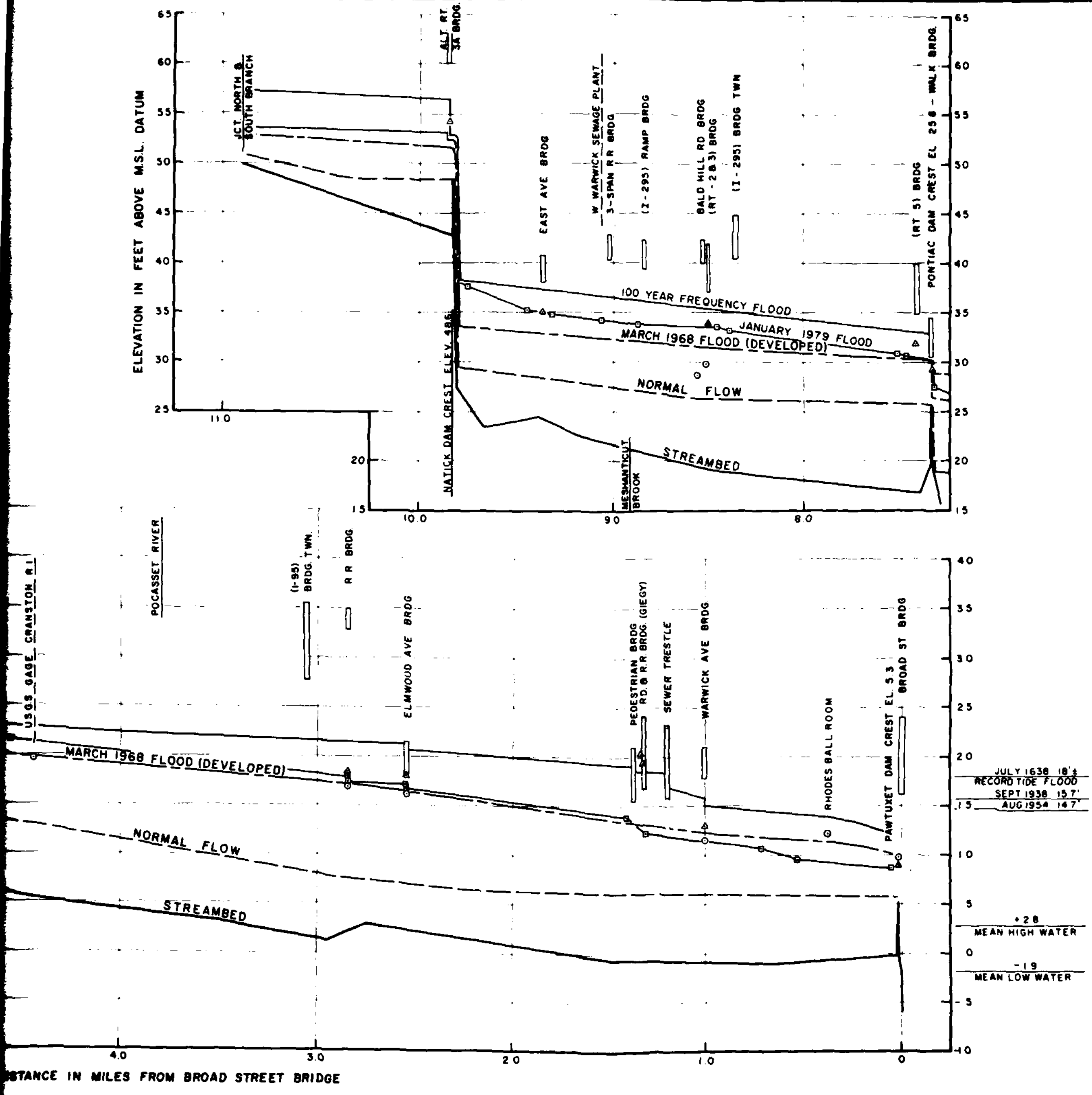
PAWTUXET RIVER PROFILE

LEGEND:

△ INDICATES H.W.M. JULY 1938

⊙ INDICATES H.W.M. MARCH 1968

⊡ INDICATES H.W.M. JANUARY 1979



PAWTUXET RIVER PROFILE

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

RIVER PROFILE

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 2-1

sludge has very high toxic amounts of heavy metals. This could cause harm to the flora and fauna of Narragansett Bay. The economic benefits to be gained by such a removal are minimal. Most of the flood prone properties in the Warwick Avenue Industrial Park would have less than a foot reduction in riverine flood stages. This proposal would have no effect on the flood stages induced by tidal surges.

As the flood control benefits to be gained by the dam removal are minimal when compared to the estimated modification costs and the potential environmental harm Federal involvement is considered unwarranted. In the future as the Pawtuxet Dam deteriorates, it is advocated that repairs or removal be judged mainly on environmental considerations.

A second dam of concern on the Pawtuxet River is the Pontiac Dam, located at river mile 7.4. This structure creates an impoundment with backwater extending upstream for several thousand feet. If the dam were to be removed, or lowered, as requested by local interests, flood stage reduction upstream of the dam under Standard Project Flood conditions would be on the order of 0.2 foot in the impounded reach (see Plate 2-1). For a 100-year frequency flood level reduction would be significantly greater, but only approaching about 2.5 feet at the dam and tapering off to one foot at Natick Dam. However, potential flood losses at a 100-year event are relatively minor.

Based on a preliminary cost evaluation it was determined that related costs involving channel improvement, rock slope protection and modification of a few bridges would exceed accrued benefits and subsequent analysis would be unwarranted.

Presently there is little flood prone development at the 100-year flood level upstream of the dam and its normal backwater pool does have some limited aesthetic appeal. In the future if the dam needs major repair, removal should be considered along with upstream measures to protect against scour and excessive degradation.

Removal of other dams that no longer serve a meaningful purpose would appear to be beneficial by reducing flood stages and damages in the immediate vicinities of such dams, but would create erosion problems downstream that would more than offset the benefits gained.

In conclusion, the removal of dams for all zones was considered to be an inadequate solution for solving flood problems on the main stem and further evaluation was deemed unwarranted.

b. <u>Diversion of Flood Flows</u> - Two basic methods could be used as an

effective means of providing flood relief to high risk flood prone areas. One would involve an intrabasin diversion of flood flows and the other an interbasin transfer.

Based on a preliminary screening damage analysis of all zones, no intrabasin scheme appeared viable and further evaluation was deemed unwarranted.

The other concept involving interbasin transfer of flood flows appeared applicable to Zones 3 and 4 and was selected for further evaluation.

- A relatively high head could be developed, thereby reducing conveyance size and project costs. A diversion would be located upstream of the heavily damaged centers and could provide substantial flood relief to flood prone areas of three communities with minimal social and environmental disruptions.

- Furthermore, the Diversion would be in close proximity to Apponaug Cove (a tidal estuary of Narragansett Bay), which would minimize the effects of fluctuation of flood flow stages. It has been determined that a diversion at Zone 3 would involve greater construction costs and would result in more environmental and social harm. Therefore, a diversion of flood flows at Zone 3 was rejected and the diversion at Zone 4 was reserved for further evaluation.

c. Channel Modification - The final stream improvement element would consist of channel modification involving a rehabilitation program for improving the waterways. The methods considered included channel widening, deepening and elimination of abrupt turns and oxbows in numerous main stem and tributary reaches.

Channel modification on tributary zones was rejected for further evaluation since existing damages are relatively minimal and unrelated to channel modification. Channel modification in all other zones was found to be economically and hydraulically impractical for flood stage reductions due to the flat hydraulic gradient of the riverbed. Furthermore, such improvement would not produce the need for floodwalls and dikes for containing flood flows. The single exception would be the need for channel modification should a potential local protection project, such as a wall or dike, encroach significantly upon the existing cross-section of the stream.

Floodproofing or Relocation - As flood problems within Zones 1, 2, 3, 4A and 7A were determined to be minimal, no further evaluation was required in those zones. For the remaining zones, floodproofing or relocation was found to warrant further evaluation.

CONCLUSIONS

The results of the initial screening show that only a limited number of measures meet the minimum acceptable plan requirements. The No Action program and all regulatory measures were retained for further analysis in all zones due to their importance in preventing or minimizing future flood problems. The results of the screening are summarized in Table 2-5.

ADVANCED SCREENING

EVALUATION OF MEASURES

The ensuing step in the plan selection and formulation process entailed refinement of individual measures that passed the preceding initial screening test. This next phase continued with a more detailed identification of the measures that could provide an adequate degree of protection in major damage areas while satisfying the economic criteria previously established that tangible benefits must exceed economic costs. These measures were evaluated on their own merits, that is, acting alone. Evaluation combinations of measures was reserved for the subsequent development of detailed plans phase. The schematic results of the advanced screening are shown in Table 2-6.

In accordance with the desires of local interests, the first element of this evaluation process centered on a nonstructural program. By design, this program would involve a blend of both regulatory and corrective measures. Regulatory measures are geared to minimizing future flood losses by controlling and restricting future development of the flood plains. As such, they do not provide an effective means of reducing flood damages caused to existing buildings, though as a measure for reducing losses to contents they would be worthy of further merit.

The initial nonstructural approach to the corrective measures would employ a floodproofing technology by which both buildings and contents would be protected to 1990 hydrologic conditions--the time frame that a project could become operable. In conformance with the stringent regulations established under the National Flood Insurance Program, the minimum level of protection considered allowable would be the levels anticipated under a 100-year flood event.

As the objective of this study would be the development of a viable flood management program for relieving present and future flooding conditions, the nonstructural program, as it pertains to corrective measures, would be the initial element of the evaluation, followed by the structural program, concluding with the other remaining measures including those involving future action. These measures are discussed in the following paragraphs.

CORRECTIVE NONSTRUCTURAL MEASURES

A major program was initiated for this phase of the plan formulation process. It involved the determination of the first floor and ground elevations of all structures that would be damaged by an event approaching a Standard Project Flood. All openings were sized and

TABLE 2-6
ADVANCED SCREENING

POTENTIAL MEASURES	1	1A	2	2A (2A-1+2)	3	4	4A
NO ACTION PROGRAM	E	E	E	E	E	E	E
REGULATORY MEASURES (ALL)	E	E	E	E	E	E	E
CORRECTIVE MEASURES							
Land Treatment Measures	5	5	FA	5	5	4	4
Reservoirs	1	5	FA	5	1, 2, 3	1, 2, 3	1
Walls & Dikes	5	1	5	1	5	1	1
Reservoir Management Program	FA	4	FA	4	4	5	4
Hurricane Barriers	6	6	6	6	6	6	6
Stream Improvement							
Removal of Dams	5	4	4	4	5	1, 3	4
Diversion of Flood Flows	4	1	4	1	2	E	1, 2
Channel Modification	5	5	5	5	5	1, 3	1, 3
Flood Proofing or Relocation	5	1	5	1	5	1	1

CRITERIA APPLIED DURING SCREENING

1. Economically Infeasible
2. Engineeringly Impractical
3. Socially Unacceptable
4. Inadequate Solution
5. No Major Needs or Problems
6. **Not Applicable**

DAMAGE ZONES

North Branch---------- 1-1A
South Branch---------- 2-2A
Main Stem------------- 3-8
Meshanticut Brook----- 4A-4B
Pocasset River-------- 6A-6B
Roger Williams Brook - 7A-7B

EENING

ZONES										
4	4A	4B	5	6	6A	6B	7	7A	7B	8
E	E	E	E	E	E	E	E	E	E	E
E	E	E	E	E	E	E	E	E	E	E
4	4	4	4	4	4	4	5	5	5	4
1, 2, 3	1	1	1, 2, 3	1, 2, 3	1	1	1, 2, 3	5	2	1, 2, 3
1	1	1	E	1*	1	1	E	5	1	E
5	4	4	4	4	1	4	4	1, 3	4	2, 5
6	6	6	1, 2, 3	1, 2, 3	6	1, 2, 3	1, 2, 3	6	1, 2, 3	1, 2, 3
1, 3	4	4	4	4	3, 4	4	4	3, 4	4	4
E	1, 2	1, 4	2	2	1	1	2	1, 4	2	2
1, 3	1, 3	1, 3	1	1	1, 3	1, 3	1, 3	5	1, 3	1, 3
1	1	1	1	1	1	1	1	5	1	1

- 1-1A
- 2-2A
- 3-8
- 4A-4B
- 6A-6B
- 7A-7B

LEGEND

#	(Step 2) Screening Further Evaluation Unwarranted
#	(Step 3) Screening Further Evaluation Unwarranted
E	Further Evaluation Warranted
FA	Future Action
*	Further evaluation warranted in part of zone in Warwick.

sill elevations taken for commercial and industrial structures within the SPF limits. For residential structures the cellar openings were approximated, but only for those within the 100-year flood limits. The nonresidential structures were analyzed individually to determine the costs of the corrective nonstructural measure. Benefits to the various measures for the most promising structures were then calculated and the traditional BCR's determined.

A computer program was derived to provide an initial screening of the residential structures. The damage figures used in the program were based on past damage surveys performed by this division for various types of homes, and the depth damage curves developed by the Federal Insurance Administration. Literature search plus in-house expertise have resulted in the following list of criteria that were to be followed for this program.

<u>Criteria Applied in Floodproofing Program</u>

a. For initial analysis unreinforced concrete walls were considered capable of withstanding the hydrostatic pressures of a 3-foot head differential between water surfaces on either side of the wall without collapsing.

b. Wood frame structures cannot be floodproofed above the sill.

c. Structurally sound buildings can be raised only three feet.

d. Where depths of water for the design condition exceed the heights of a. and c. above, relocation would be necessary.

e. Ring wall enclosures were considered for purposes of tying a building's wall into high ground only.

f. At the design flood conditions, all structures that could potentially be inundated were floodproofed and/or raised if necessary, even though only nuisance basement flooding would occur.

g. The drag line effect (the difference in water levels due to passage of flows through soil) was not considered in this phase of analysis. There are too many variables such as soil permeability, drainage nets or patterns, condition of the concrete slab and wall, the tightness of any joints or seams etc., to accurately predict the true effects.

h. Uplift pressures were not considered.

With this above criteria, an economic analysis of the lower main stem (Zones 3 to 8 including backwater reaches) was conducted to determine

the viability of floodproofing. Costs were developed for all structures for two levels of flooding, namely the Standard Project Flood and the 100-year flood.

Results of this analysis are tabulated by category in Table 2-7 and by community/category in Table 2-8. These tables represent total costs of floodproofing structures in the flood hazard areas under existing conditions. The requirements of floodproofing would involve a cost sharing between the Federal Government and the property owner which are established and Section 73b of the 1974 Water Resources Development Act. The costs to non-Federal interests are not to exceed 20 percent of the total projects first cost. The number of affected structures in the tables represent ownerships which could include a complex of structures such as a manufacturing concern or commercial plaza. Thus the Warwick Mall and Ciba Geigy are handled in these tables as constituting only one structure each.

The costs noted in both tables also include the costs associated with relocation of structures. At the Standard Project Flood level, approximately 616 structures, equivalent to 33 percent of the total number of structures located in the SPF flood area, would have to be relocated. Eighty-three of these structures represent commercial or industrial establishments employing in excess of 5,700 people. At the 100-year flood level, approximately 26 structures would have to be relocated, of which 14 are commercial or industrial firms employing about 2,500 people.

Although floodproofing measures would be considered only to the 100-year flood event, cost reflecting the Standard Project Flood condition were derived as a means of demonstrating an order of magnitude.

It is evident from the figures shown in Table 2-7 where the Benefit to Cost ratios for the 100-year and the Standard Project Flood are .10 and .04 respectively, that this alternative as a total system is not economically feasible. While it would allow portions of riverbank to be converted to a greenbelt area, the social ramifications would be significant--as about 65 homes would have to be either raised or relocated at a 100-year flood event. In addition, 18 industrial and commercial establishments would have to be relocated, resulting in the direct loss of over 100 jobs. At the Standard Project Flood analysis, although more theoretical, the losses are much more significant. Table 2-9 lists these relocations by major land use category.

The benefit to cost ratio for single structures was also analyzed for those that had high losses and/or low corrective costs. It was determined, with the aid of the computer program for residential

TABLE 2-7
FLOODPROOFING -
COSTS AND AFFECTED OWNERSHIPS
(By Category)

1978 CONDITIONS AND PRICE LEVELS
ALL VALUES x $1,000

Category	100-Year Flood		Standard Project Flood	
	#	Value	#	Value
Commercial	42	17,000	82	115,130
Industrial	23	36,280	40	120,650
Residential	393	3,660	1,076	44,020
Public	5	150	11	3,490
Schools	2	80	5	3,350
Others	6	290	12	7,510
TOTAL	471	$57,480	1856	$294,170
Amortized over a 50 year life 6-5/8 = .069078		$3,971		$20,321
Annual Benefits		380*		760*
Approx. Benefits to Relocated Structures		90		820
B/C Ratio		.10		.04

* Excludes benefits to relocated structures, (equal to approximately $88,000 and $820,000 for 100 year and SPF flood respectively), nonphysical losses, exterior losses, roads and utilities.

TABLE 2-8
Floodproofing -
Costs and Affected Ownerships
(By Category and Community)

Community/ Category	100-Year Flood		Standard Project Flood	
	#	$1,000	#	$1,000
WARWICK				
Commercial	21	15,000	44	104,600
Industrial	13	17,090	19	40,380
Residential	146	1,470	570	17,050
Public	2	70	2	1,290
Schools	0	0	0	0
Others	3	60	4	2,120
TOTAL WARWICK	185	$33,690	639	$165,440
CRANSTON				
Commercial	11	1,130	27	8,300
Industrial	6	18,810	16	79,200
Residential	206	1,220	1,083	23,930
Public	2	40	8	1,710
Schools	1	50	2	1,180
Others	2	220	5	4,540
TOTAL CRANSTON	228	$20,450	1,141	$118,860
WEST WARWICK				
Commercial	10	890	11	2,230
Industrial	4	370	5	1,100
Residential	41	980	53	3,040
Public	1	50	1	490
Schools	1	40	3	2,160
Others	1	10	3	850
TOTAL WEST WARWICK	58	$2,340	76	$9,870
TOTAL	471	$56,480	1,856	$294,170

TABLE 2-9

NONSTRUCTURAL CORRECTIVE MEASURES ANALYSIS
RELOCATION REQUIRED BY CATEGORY AND ZONE

	Zone	100-Yr Flood	Standard Project Flood
Commercial	4	2	26
	5	1	3
	6	4	10
	7	1	4
	8	-	6
Residential	4	-	216-175 in Meshanticut River
	5	0	0
	6	-	159-150 in Pocasset River
	7	12	142
	8		
Industrial	4	1	8
	5	1	9
	6	3	4
	7	-	3
	8	-	9
TOTAL	4	3	250
	5	2	12
	6	7	173
	7	13	149
	8	0	15

structures and individual analysis for nonresidential, that only several homes in the basin were considered marginally feasible for floodproofing. It was then decided that if the conservative evaluation criteria was analyzed structurally the unreinforced concrete walls would fail at a much lower head differential and that this buoyancy effect would probably result in all floodproofed homes floating away. Thus further evaluation as a single purpose Federal project was terminated.

In summation, floodproofing measures acting as entities by themselves would not satisfy the benefit-cost criteria. When combined in a system with other measures, such as the structural program, they could conceivably be a valuable asset to the flood management plan for the basin. Such alternative considerations were evaluated in the detailed plan phase.

STRUCTURAL PROGRAM

As previously discussed, flood losses occur principally in the heavily urbanized areas located along the lower end of the main stem. The most economical methods of containing these floodwaters to either reduce flood stages and/or alleviate flooding conditions would appear to be local protective works involving a system of dikes, walls and channel modification, or diversion of flood flows.

The first element in this evaluation process concerned a local protective plan consisting of Preliminary Plan A and A-1. Preliminary Plan A would provide flood protection equivalent to the Standard Project Flood (SPF) level and Preliminary Plan A-1 for the 100-year flood event. These plans would establish a range of values for determining maximization of net tangible economic benefits. In addition, the minimum level would also be employed in comparing results of the structural with those of the nonstructural program involving floodproofing measures. In providing the required degree of protection, Plan A would require 13 individual local protection projects; seven of which would be located in Warwick, five in Cranston and one in West Warwick. In total, the plan would require 39,300 linear feet of dikes, 23,400 linear feet of floodwalls and 7,700 linear feet of channel modification, plus provisions for temporary closures of railroad and highway openings at 21 locations. In addition to the normal pumping facilities for controlling the interior drainage systems during flood stages, a major pumping station at the outlet of Meshanticut Brook would also complement the plan. Respective pertinent data together with a general layout of Plan A are shown in Table 2-10 and Plate 2-2.

The preliminary project cost of Preliminary Plan A would be $38.0 million. With costs converted to an annual charge and weighed

TABLE 2-10

PERTINENT DATA - PRELIMINARY PLAN
S.P.F. -- NATURAL CONDITIONS

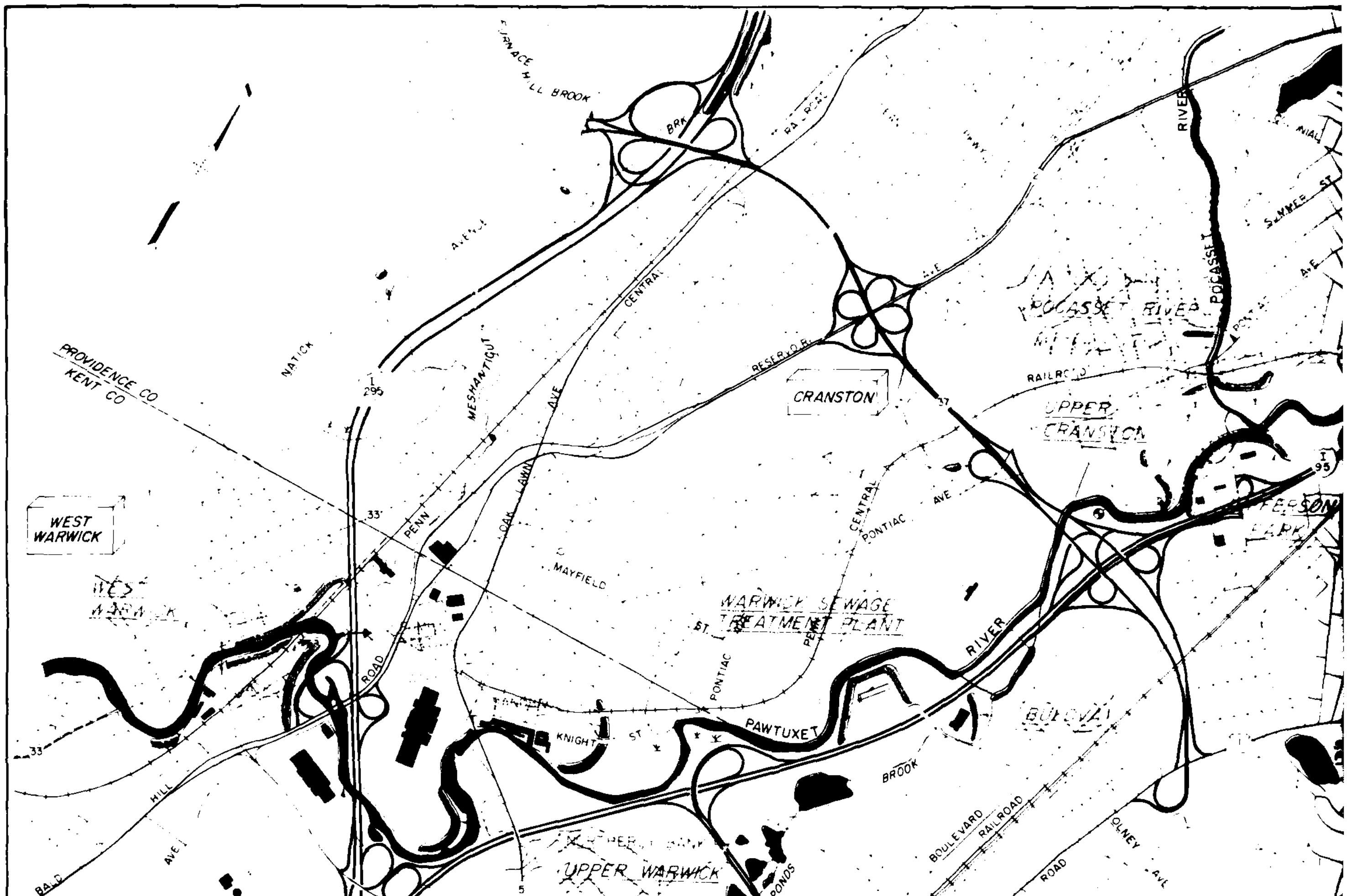
Project Name	Flood Elevation m.s.l.[2]	Normal W.S. Elevation m.s.l.[3]	Feet[4]	CONCRETE FLOOD WALLS[1] Average Height Feet	Maximum Height Feet	Length Feet	EARTH DIKES[1] Average Height Feet	Maximum Height Feet	Length Feet	Channel Modification Length (ft)	GATE CLOSURES Sets	Type
WARWICK												
Warwick Ave.	21.0 to 26.3	5.5 to 6.0	15.5 to 20.3	13	18	2400	15	20	4400	1000	3	2-Vehicular 1-Pedestrian
Elmwood Ave.	27.0 to 29.5	6.2 to 7.4	20.8 to 22.1	13	12	500	15	18	4400	0	1	Vehicular
Jefferson Park	33.1 to 33.7	9.3 to 12.0	23.8 to 21.7	16	16	200	15	20	2700	2400	None	
Bulova	33.8 to 33.9	14.6 to 15.1	19.2 to 18.8	0	0	0	11	14	1200	0	None	
Warwick Sewage Treatment Plant	33.9 to 34.1	15.3 to 16.6	18.6 to 17.5	0	0	0	14	17	2500	0	None	
Upper Warwick Northerly Bank	37.4 to 45.1	18.3 to 27.1	19.1 to 18.0	18 and 15	22 and 19	1000 and 3000	15 and 20	19 and 21	1600 and 1800	0	3 1	Sandbags Vehicular
Upper Warwick Southerly Bank	44.1 to 46.4	26.2 to 28.2	17.9 to 18.2	10	12	3800	15	21	3800	0	1 1	Vehicular Railroad
WEST WARWICK												
West Warwick	45.4 to 46.4	27.6 to 28.7	17.8 to 17.7	16	16	1800	16	20	2400	0	1 1	Railroad Vehicular
CRANSTON												
Rhodes	19.7 to 20.7	5.8 to 5.9	13.9 to 14.8	18	18	2200	15	20	900	0	None	
Cranston	21.5 to 31.0	6.0 to 7.9	15.5 to 23.1	13	19	4700	12	19	6100	0	3 1	Vehicular Pedestrian
Upper Cranston	33.5 to 33.8	11.5 to 13.4	20.0 to 20.4	10	13	2100	18	20	1000	0	None	
Pocasset River Westerly Bank	33.0 to 33.0	10.8 to 12.5	22.2 to 20.5	16	24	900	12	20	600	0	1 1	Vehicular Railroad
Pocasset River Easterly Bank	33.0 to 33.0	10.8 to 23.0	22.2 to 10.0	14	16	800	16 and 8	20 and 12	5900	4300	2 1	Vehicular Railroad
			TOTALS			23,400 4.4 mi.			39,300 7.4 mi.	7,700 1.5 mi.		

1 Dimensions as observed from the landside portion to the top of the protective works.

2 Indicates the range of expected heights of flood waters.

3 Indicates the range of normal river elevations.

4 Indicates a range of the depth of flood waters above normal river stages.



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RAILROAD
UPPER CRANSTON
WEST WARWICK
MAYFIELD
WARWICK SEWAGE TREATMENT PLANT
PONTIAC AVE
PENN
OAK LAWN AVE
ROAD
KNIGHT ST
PAWTUXET RIVER
BROOK
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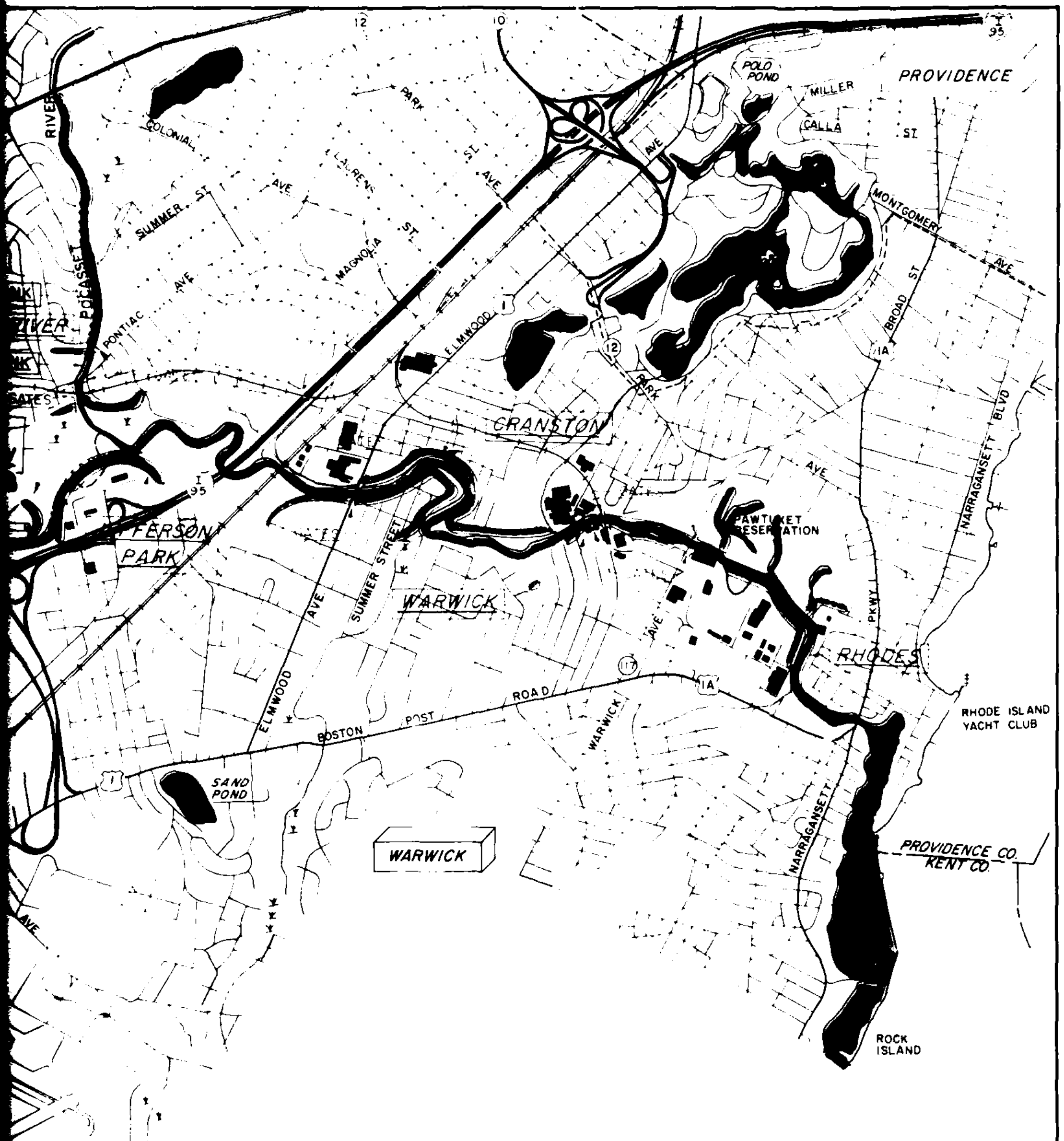
SCALE IN FEET
LEGEND



LEGEND

- City or County Boundary Line
- Town Boundary Line
- Municipal Sewage Treatment Facility
- U.S.G.S. Gaging Station
- Tributaries
- Ponds or Major Rivers
- Local Protection Projects
- Earth Dikes
- Concrete Flood Walls
- Channel Modification

NOTES

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2. Only commercial and industrial buildings having a bearing on project report are shown.
3. Although pumping stations are required for all local protection projects only those controlling major interior drainage areas are shown

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WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND
ALTERNATE A
STANDARD PROJECT FLOOD

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 2-2

against the derived benefits, the plan as a system is not economically justified. By evaluating individual segments of the plan, two local protection projects, Warwick Avenue and the Bulova Complex have benefit-cost ratios that exceed unity. A third project, Elmwood Avenue, is being retained for further detailed analyses because of the high frequency of flooding, the number of homes subject to inundation, the water quality degradation and public health aspects of having this area, all with septic tank disposal systems, inundated, and the high degree of local support for any degree of assistance in this scheme.

Preliminary Plan A-1 would entail the same number of projects at identical locations for the same communites, but for a lower level of flood protection. In total, the plan would include 25,800 linear feet of dikes, 16,500 linear feet of concrete walls and 3,300 feet of channel modification. Considerations for temporary closures of railways and highway openings would be required for Plan A. A general layout of this alternative plan is shown on Plate 2-3, with pertinent data appearing in Table 2-11.

The total project cost of Preliminary Plan A-1 would be $30 million. Even with this lesser degree of flood protection at a lower stage level, the Preliminary A-1 plan would be economically unjustified. Segmenting the plan into individual components, and including economic growth factors, the two same local protection projects, Warwick and the Bulova Complex would be economically justified. Elmwood Avenue project again is being retained because of the Social and Environmental aspects.

Comparison of costs, annual charges and benefits pertaining to the total plan and justified segments of both Preliminary Plans A and A-1 are shown in Table 2-12. These costs are exclusive of the pumping stations, lands and damages, and are only preliminary based on a minimum acceptable dike and wall cross sections. These costs are based on preliminary 1973 materials costs and updated to 1978 levels. It is important to note that these wall and dike costs cannot be compared to the more detailed project costs derived later in this section. For example, the Warwick Avenue project listed in Table 2-12 costs $5.2 million. Under a more detailed set of design conditions including foundation and material analyses, the cross sections were significantly changed. The resultant cost was over $13 million, or an increase of over 250 percent.

As noted in Appendix 1, a flood control survey report prepared by the Corps in 1939 led to 1941 authorization of a flood control plan for the basin. Part of the plan entailed a gated diversion plan, known as the Pontiac Diversion, that would divert floodwaters from the main river generally southward through a diversion channel that would discharge at the head of the inner basin at Apponaug Cove, the

TABLE 2-11

PERTINENT DATA - PRELIMINARY PLAN
100-YEAR FLOOD -- NATURAL CONDITIONS

				CONCRETE FLOOD WALLS[1]			EARTH DIKES[1]				GATE CLOSURES	
Project Name	Flood Elevation msl[2]	Normal W.S. Elevation msl[3]	Feet[4]	Average Height Feet	Maximum Height Feet	Length Feet	Average Height Feet	Maximum Height Feet	Length Feet	Channel Modification Length (ft)	Sets	Type
WARWICK												
Warwick Ave	13.8 to 17.5	5.5 to 5.9	8.3 to 9.6	6	10	2400	7	11	3400	1000	2	Vehicular
Elmwood Ave	18.8 to 20.5	6.2 to 7.3	12.6 to 13.2	6	7	500	7	10	4400	0	1	Vehicular
Jefferson Park	22.8 to 23.4	9.9 to 12.0	12.9 to 11.4	6	6	200	6	10	2400	2300	None	
Bulova	25.2 to 25.4	14.6 to 15.1	10.6 to 10.7	0	0	0	5	7	1000	0	None	
Warwick Sewage Treatment Plant	25.5 to 26.3	15.3 to 16.3	10.2 to 10.0	0	0	0	7	9	2300	0	None	
Upper Warwick Northerly Bank	29.0 to 33.8	18.3 to 25.9	10.7 to 7.9	10 and 10	14 and 12	1000 and 1100	8	12	1000	0	None	
Upper Warwick Southerly Bank	36.7 to 38.0	27.0 to 28.8	9.7 to 9.2	4	5	1400	8	11	3100	0	1	Vehicular
WEST WARWICK												
West Warwick	37.0 to 37.9	27.6 to 28.7	9.4 to 9.2	7	7	1700	7	10	2400	0	1	Vehicular
CRANSTON												
Rhodes	13.7 to 14.7	5.8 to 5.9	7.9 to 8.8	10	10	1800	7	12	700	0	None	
Cranston	16.7 to 22.3	6.0 to 7.6	10.7 to 14.7	8	14	4500	9	13	3800	0	3	Sandbags
Upper Cranston	23.4 to 23.9	12.9 to 13.4	10.5 to 10.5	6	8	900	0	0	0	0	None	
Pocasset River Westerly Bank	23.0 to 23.0	10.8 to 12.5	12.2 to 10.5	12	14	800	6	10	400	0	2	Sandbags
Pocasset River Easterly Bank	23.0 to 23.0	10.8 to 12.0	12.2 to 11.0	5	8	200	8	10	900	0	None	
			TOTALS			16,500 3.1 mi			25,800 4.9 mi	3,300 0.6 mi		

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2 Indicates the range of expected heights of flood waters.

3 Indicates the range of normal river elevations.

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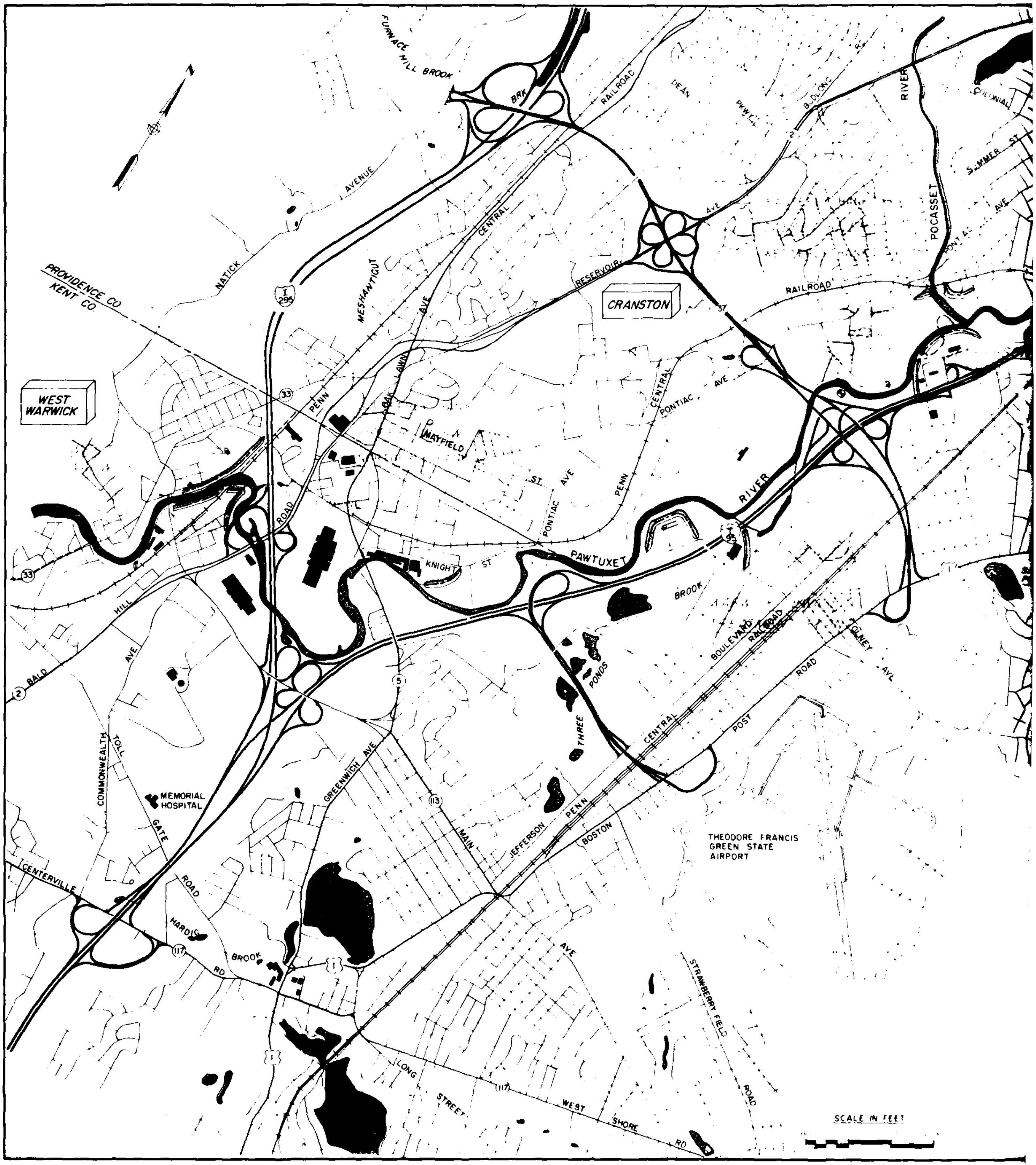

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RESERVOIR
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POST ROAD
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TOLL GATE
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MEMORIAL HOSPITAL
GREENWICH AVE
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BOSTON
THEODORE FRANCIS
GREEN STATE
AIRPORT
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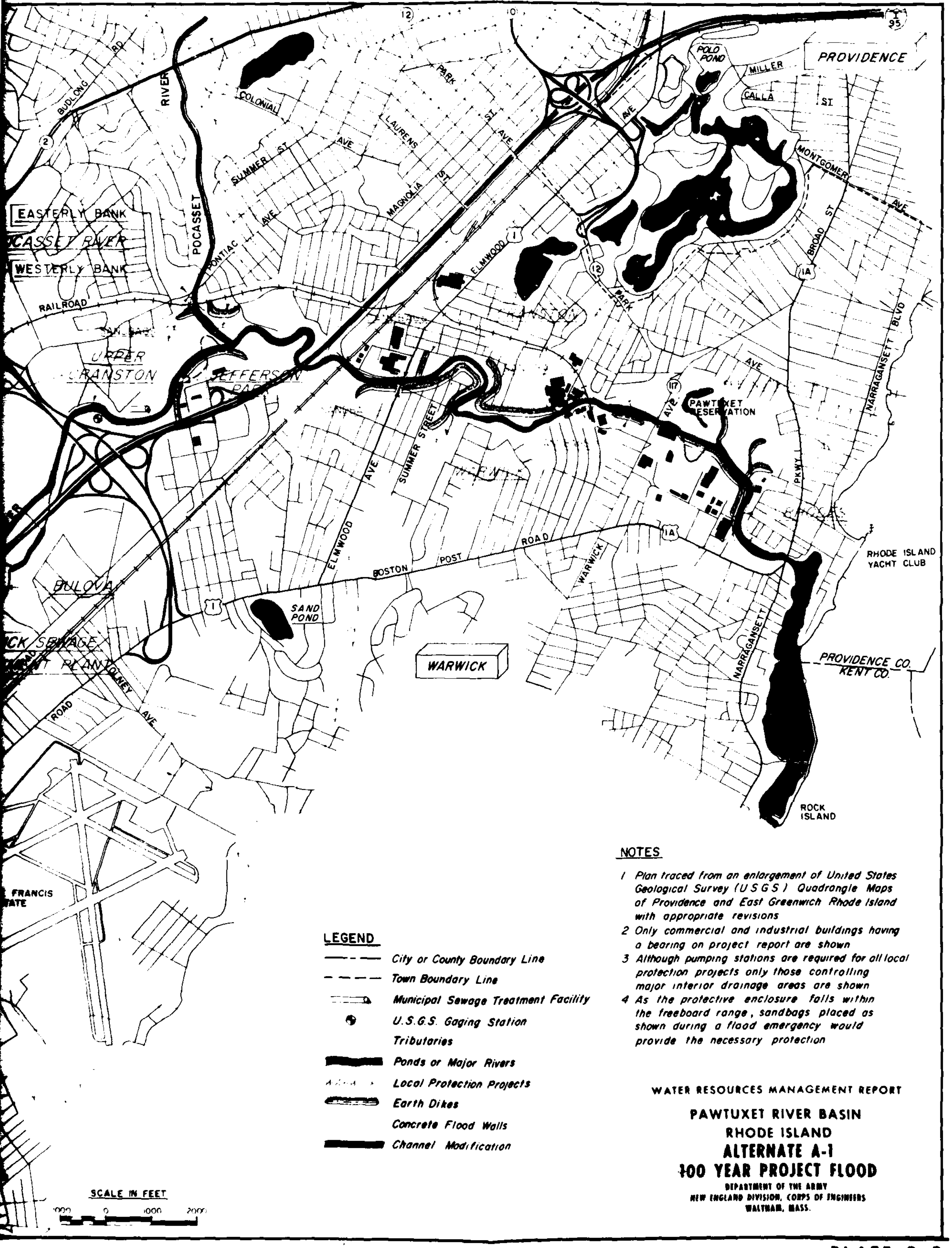

NOTES

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2. Only commercial and industrial buildings having a bearing on project report are shown
3. Although pumping stations are required for all local protection projects only those controlling major interior drainage areas are shown
4. As the protective enclosure falls within the freeboard range, sandbags placed as shown during a flood emergency would provide the necessary protection

LEGEND

- City or County Boundary Line
- Town Boundary Line
- Municipal Sewage Treatment Facility
- U.S.G.S. Gaging Station
- Tributaries
- Ponds or Major Rivers
- Local Protection Projects
- Earth Dikes
- Concrete Flood Walls
- Channel Modification

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND
ALTERNATE A-1
100 YEAR PROJECT FLOOD

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 2-3

TABLE 2-12

ECONOMIC ANALYSIS FOR PRELIMINARY

PLANS A AND A-1

	ALTERNATE A Standard Project Flood				ALTERNATE A-1 100-Year Flood			
Name	Cost	Annual Charges	Annual Benefits	Benefit to Cost	Cost	Annual Charges	Annual Benefits	Benefit to Cost
WARWICK								
Warwick Avenue	5,236,000	471,100	420,200	.89	3,819,900	318,300	267,400	.84
Norwood	4,298,300	296,000	112,500	.38	3,070,200	211,500	84,500	.40
Jefferson Park	4,165,000	316,500	16,700	.05	1,999,200	149,900	11,700	.08
Bulova	1,499,400	100,000	120,000	1.20	999,600	66,600	63,300	.95
Warwick Sewage Treatment Plant	1,832,600	149,900	20,000	.13	999,600	66,600	16,700	.25
Upper Warwick Northerly Bank	9,329,600	699,700	188,300	.27	2,332,400	183,300	60,000	.33
Upper Warwick Southerly Bank	5,664,400	449,800	48,300	.11	2,165,800	183,300	1,700	.01
WEST WARWICK								
West Warwick	4,165,000	333,200	66,600	.20	1,832,600	149,900	51,600	.34
CRANSTON								
Rhodes	2,998,800	216,600	13,300	.06	2,165,800	149,900	11,700	.08
Cranston	13,161,400	1,066,200	299,900	.28	8,496,600	726,400	239,200	.33
Upper Cranston	3,498,600	283,200	11,600	.04	833,000	66,600	6,700	.10
Pocasset River Westerly Bank	1,332,800	116,600	9,300	.07	833,000	66,600	5,000	.08
Pocasset River Easterly Bank	3,665,200	299,900	25,000	.08	499,800	33,300	5,000	.15
TOTAL	60,847,100	4,798,700	1,350,700	.28	30,047,500	2,362,200	824,500	.35

NOTE:

Annual charges and benefits are based on an interest rate of 6 and 7/8 percent (the prevailing rate at the time of the economic evaluation) and on 1976 dollars and then updated to September 1978 dollars.

Costs do not include lands and damages, pumping stations and rights-of-way.

northwestern arm of Greenwich Bay. Due to lack of local assurances in cost sharing, the project remained in limbo until its authorization expired in 1951.

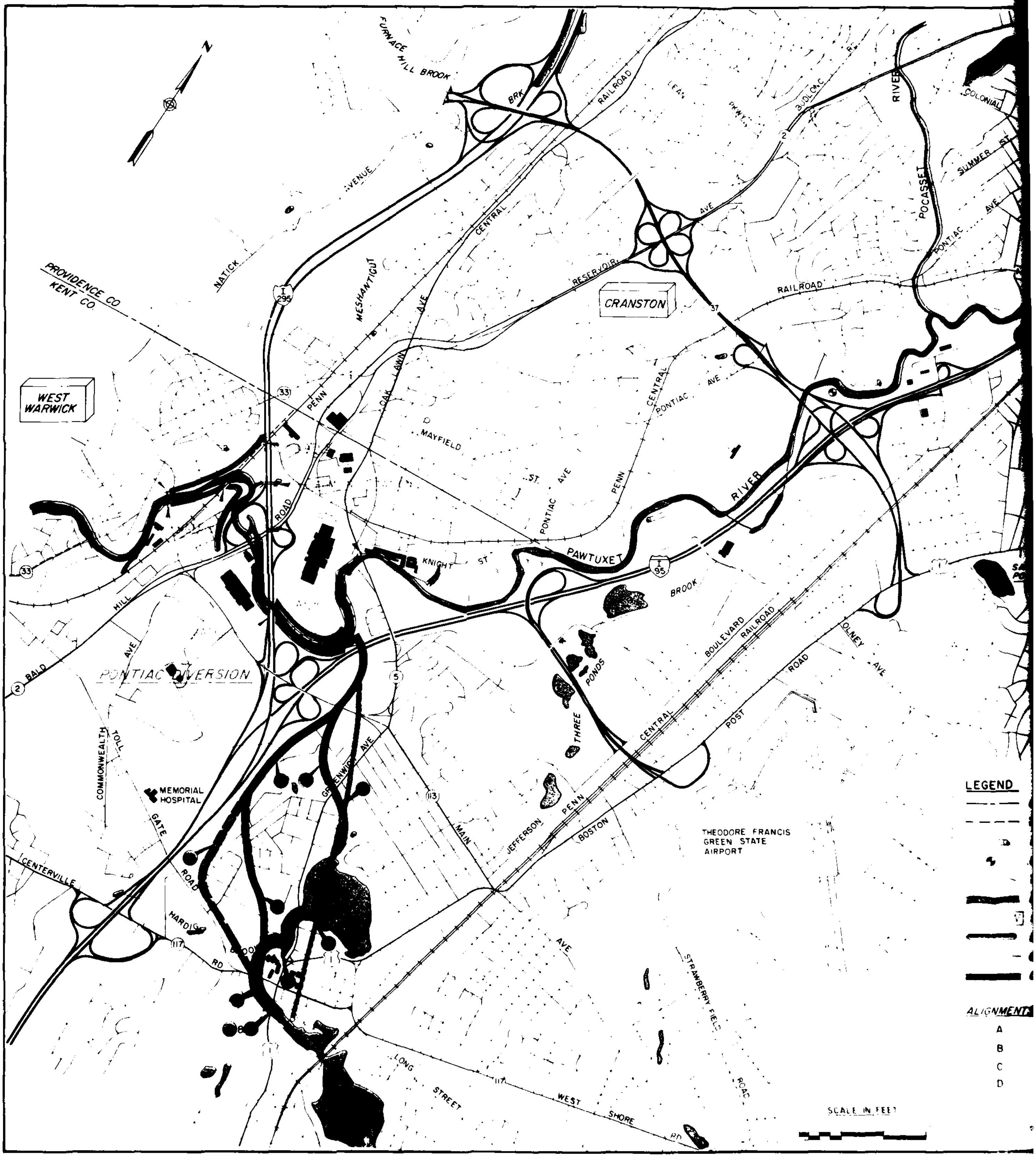
Present evaluation of a new proposal would accomplish substantially the same function. However, the proposal would entail a variation in alignment with a totally new concept for the intake channel. This proposal would also retain its identification as Pontiac Diversion.

The Pontiac Diversion is shown on Plate 2-4 and would consist of three components--intake structure, outlet works and the actual tunnel-channel. Four different diversion alignments were analyzed. However, all had the same intake channel and the outlet works into the head of Apponaug Cove. The intake channel requirements have changed significantly since the prior study. Route 95, 295 and the Warwick and Midland Malls have all been built in the immediate area of the intake structure. Because of the height requirements of the control dam, significant portions of the above areas will be inundated whenever the diversion operates. This would necessitate that a system of walls and dikes be constructed to protect these new areas. The dikes and walls would be about 17 feet high and cover a length of over 17,500 feet. In addition, 3,200 feet of channel modification, five closures for highway and railroad openings and a massive pumping station to control flows from Meshanticut Brook would be required.

The outlet works would be located at Hardig Brook, just north of Route 1 in its tidal range. Such construction would necessitate possible major modifications to the Route 1 bridge, the shoreline of the upper cove, and the railroad bridge underpass, about 1,000 feet south of this location.

Both Alignments A and B, with respective lengths of 10,400 and 10,200 feet, would involve two segments consisting of a reinforced concrete open channel joined by a concrete lined tunnel constructed by a "cut and cover" method. Both alignments would now require extensive land taking with a minimum number of 10 homes requiring relocation or acquisition.

Alignment C would entail a diversion route through Gorton Pond where massive control gates would be provided to regulate subsequent discharges into Apponaug Cove. This alignment would have a net length of 6,600 feet (exclusive of Gorton Pond) and would consist of an open channel with reinforced concrete walls. Substantial acquisition of prime land and a minimum of eight residential or commercial buildings would be required.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THEODORE FRANCIS GREEN STATE AIRPORT
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A
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C
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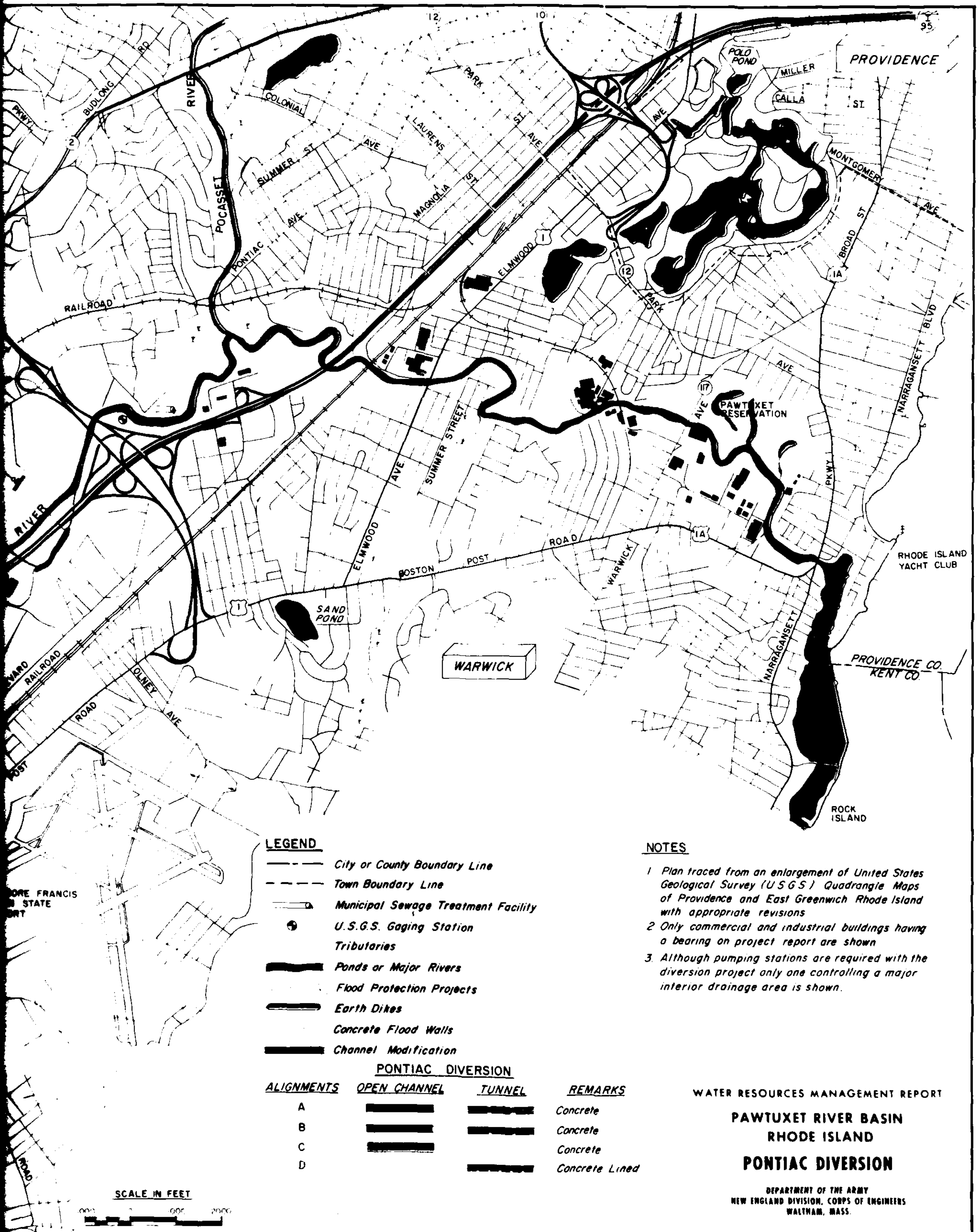

NOTES

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2. Only commercial and industrial buildings having a bearing on project report are shown
3. Although pumping stations are required with the diversion project only one controlling a major interior drainage area is shown.

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

PONTIAC DIVERSION

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 2-4

The water quality of the Pawtuxet River at the point of the diversion is officially classified as "Class C." However, recent studies indicate that the quality is significantly lower due mainly to a high concentration of coliform bacteria. As the floodwaters would be diverted through Gorton Pond, a local recreation area, having Class B waters, significant additional adverse environmental degradation can be expected to occur. Because of the relocations, the new intake channel requirements and the environmental harm, this alignment was also eliminated from further study.

Alignment D, considered to be most suitable for the diversion proposal, would consist of an 8,000-foot long, reinforced concrete lined tunnel driven through bedrock. As the quantity of flood flows to be diverted would be proportional to the head differential developed between the intake and outlet, and to the cross-sectional area of the tunnel, various tunnel diameters under different heads were developed.

Rock excavation costs for tunnel diameters ranging from 20 to 35 feet were evaluated by a computer-cost analysis program (COSTUN) and results combined with costs of related features of the intake channel.

The minimum costs for the above alignments would exceed $70 million based on 1972 valuations for construction material and relocation costs. Converted annually, this would amount to about $5.5 million. In addition to these high costs, significant social impacts, opposition by local interests and a high degree of environmental degradation resulted in all four alignments being dropped from further analyses.

An alternative to the Pontiac Diversion proposals was also studied. This alternative, with its intake located about 10,000 feet further upstream, was called the Natick Diversion due to its proximity to the Natick Dam. It would direct excess main stem flows through a driven rock tunnel from a point in the river located immediately downstream from the existing Natick Dam to an outfall in the middle of Apponaug Cove.

This scheme would provide substantial flood protection to existing developments in downstream communities. It would be able to divert floodwaters at a lesser cost due to the elimination of the walls and dikes, as well as reduced real estate costs due to elimination of the need to take any homes. Its alignment is shown on Plate 2-5.

In determining preliminary cost estimates of the Natick Diversion proposal, a computer cost analysis program (COSTUN) for tunnels was utilized. Methods involving conventional drilling and blasting, and

a mechanical mole for four tunnel sizes ranging from 20 to 33 feet in diameter with reduction in flows from 5,000 cfs to 18,500 cfs were analyzed. It was determined that most of the tunnel diameters considered were economically justified. All justified plans were held in abeyance for further analysis in the development of detailed plans.

FUTURE ACTION

In order to strengthen the flood management program and provide long-range solutions to the problems and needs of the study area, it will be essential to have the cooperation of all flood prone communities, concerned State agencies and other interested parties. Such an opportunity exists in the consideration of the three remaining corrective measures noted in Table 2-5, namely, reservoir construction with emphasis directed to the State-proposed Big River Reservoir project, reservoir management and land treatment measures. At this stage of the plan formulation efforts, these measures were considered to be future action (FA) programs implementable by local interests.

The management and/or regulation of two reservoirs (the existing Scituate and the proposed Big River Reservoirs in Zones 1 and 2, respectively) to reduce peak flood discharges and resulting damages could be an integral part of the flood management program. One of the basic elements in such a complementary reservoir management program would be providing additional floodwater storage at Big River Reservoir together with a change in mode of operation at Scituate Reservoir.

The Southeastern New England (SENE) comprehensive study recommended early construction of the Big River Reservoir as a potential water supply for the Providence Metropolitan area. It was previously under preliminary design by the Rhode Island Water Resources Board as a single purpose water supply reservoir.

As a future action, consideration should be given to increasing the height of the proposed dam by a small increment, by approximately 2.5 feet to provide additional flood protection to downstream areas, particularly the South Branch. This increased height would provide about 9,500 acre-feet of flood control storage, equivalent to about 6 inches of runoff from a drainage area of 29.7 square miles, at a minimum cost and minimum increase in environmental impact.

Additional flood storage at Scituate Reservoir would serve only to reduce the required size of downstream structures, rather than eliminate the need for them. Also the costs providing added storage at Scituate were found to be greater than the corresponding increases

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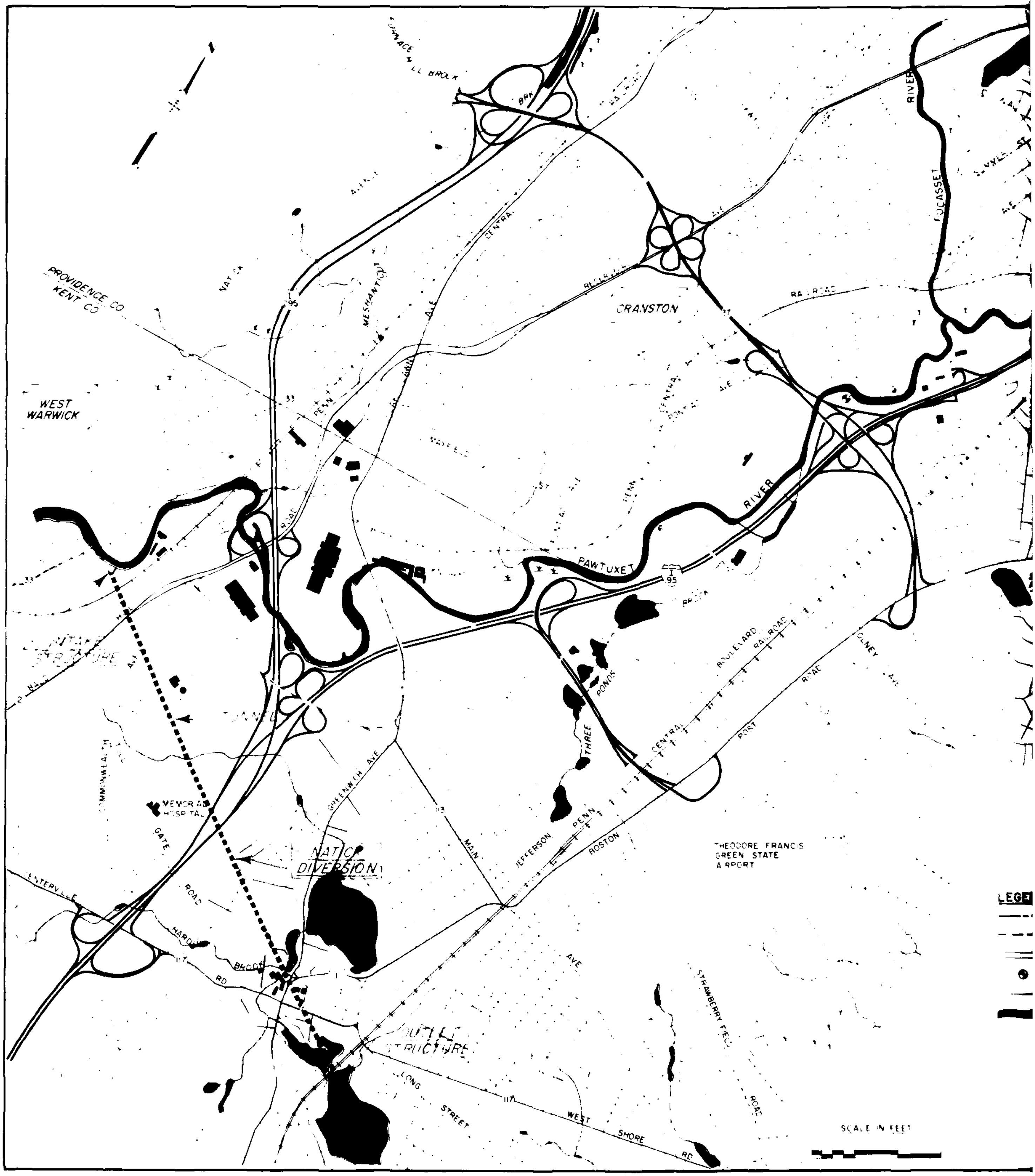

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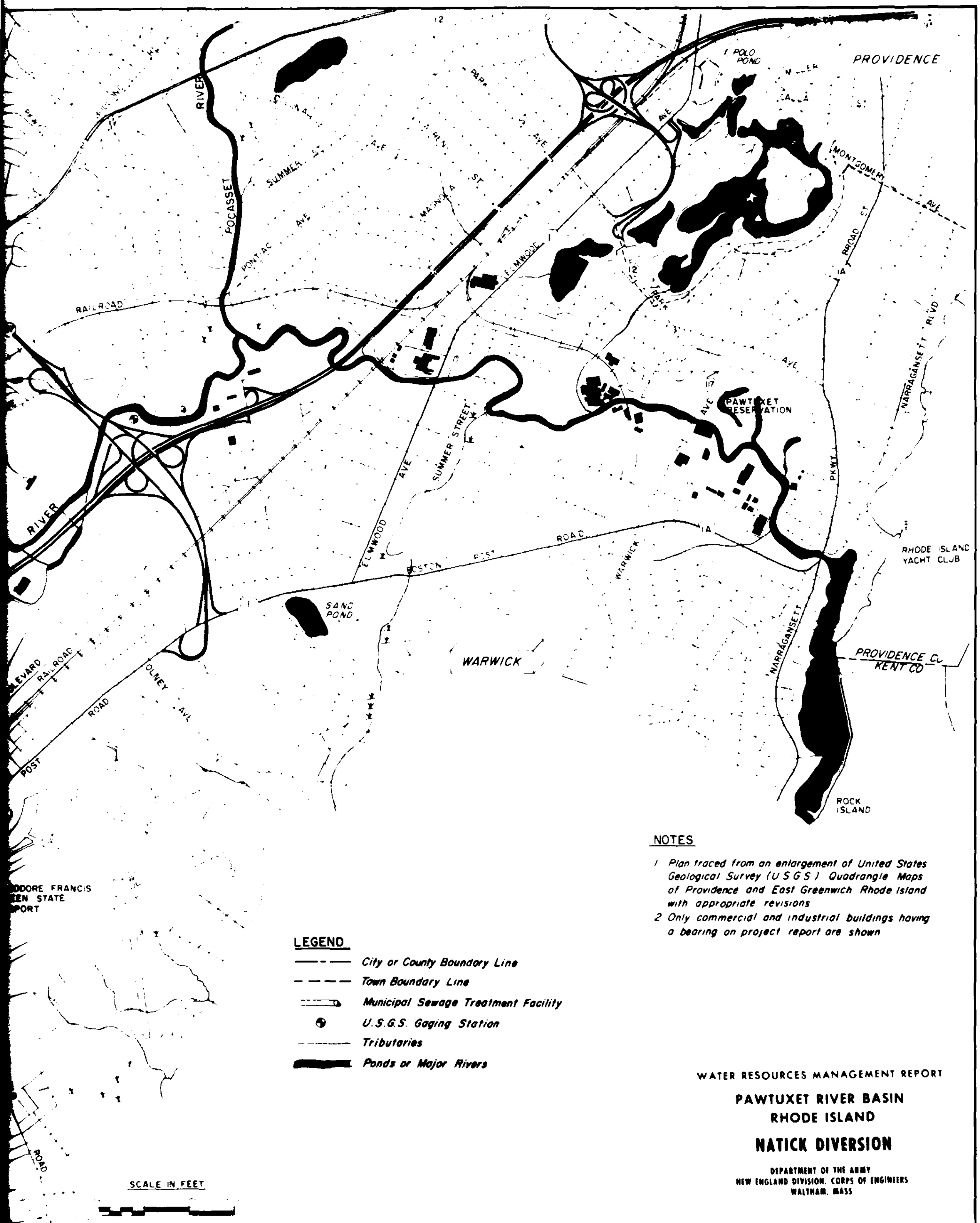

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2. Only commercial and industrial buildings having a bearing on project report are shown

LEGEND

- City or County Boundary Line
- Town Boundary Line
- Municipal Sewage Treatment Facility
- U.S.G.S. Gaging Station
- Tributaries
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WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

NATICK DIVERSION

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

PLATE 2-5

in the size of downstream projects. Therefore, no further consideration was given to adding flood storage at Scituate Reservoir. However, some additional flood control protection might be obtained through an optimum system operation of Big River and Scituate Reservoirs. This could be accomplished by developing a mode of operation whereby storage could be drafted prior to predictable refill periods, thereby minimizing unnecessary spillage while providing incidental flood control storage, and needed downstream flow augmentation. As Scituate Reservoir will eventually be operated as a system with Big River Reservoir, an arrangement and agreement to optimize the vast water resource of both systems should be explored as a future action, either prior to or following the construction of Big River Reservoir with action implementable by local interests.

Presently, Scituate Reservoir operates solely as a water supply system with its storage capability being cautiously maintained at its maximum level whenever possible. Consequently, its present value as a flood control impoundment is unreliable. Undoubtedly, its potential for providing incidental flood control storage will continue. However, with a reservoir management program forming a future increment of a flood management plan for the basin, provision for a change in mode of operation and provision for substantial floodwater storage at Big River Reservoir would be in the best interest of downstream communities. Such a plan of operation at Scituate would not necessarily infringe on the firm domestic water supply of the system but would optimize the overall system operation in the best interests of the general public.

The primary objective of land treatment measures as a future action for Big River Reservoir would simply be to alert the proper authorities concerning erosion and sediment problems which could occur with construction of the Big River Reservoir. Control of erosion associated with construction activities should be an imperative prerequisite to any land and water resource management program. Erosion control measures should be coordinated with ongoing Soil Conservation Service programs of the U.S. Department of Agriculture.

CONCLUSION

The results of the advanced screening phase are shown in Table 2-6 and are summarized in the following paragraphs.

The nonstructural corrective measure of floodproofing was found to be economically infeasible for Federal involvement as a single action program. However, it was retained for further consideration as a supplement to four potential structural measures (Natick Diversion, Bulova Local Protection, Warwick Avenue Local Protection and Elmwood

Avenue Local Protection) that appeared to warrant further consideration. The corrective measures of reservoir management for Zones 1 and 2, provision for floodwater storage at the proposed Big River Reservoir for Zone 2, and land treatment measures during the construction of Big River Reservoir were retained as a Future Action program, implementable by local interests.

The No Action and regulatory measures programs were also retained for further analysis for all zones. By their nature, these programs are ineffective in reducing flood losses to existing flood plain development, but they may be used to prevent or control future development. Both programs were retained for further consideration as supplements to specific corrective measures.

DETAILED ANALYSES OF THE SINGLE PURPOSE ALTERNATIVES

From the previous iteration, five independent corrective measures were selected for more in-depth analyses. This phase would necessitate detailed cost estimates for all measures as well as more definitive hydrologic studies and economic growth projections. Corrective nonstructural measures were eliminated in the previous analyses because they failed to meet the benefit to cost criteria necessary for Federal involvement or participation. Should any interest desire to floodproof, raise or relocate his structure, it is recommended that they obtain all necessary elevations and technical criteria from this office.

Although Federal participation in other regulatory measures is possible, most can be fully accomplished by instituting and enforcing the provisions of the Regular Program of the National Flood Insurance Program. Strict adherence will assure that the zoning requirements are met and that subdivisions cannot be located within the limits of the 100-year flood. Minor changes in building codes can also be effected, resulting in further protection from flooding.

Detailed analyses of each single purpose measure follows.

WARWICK AVENUE LOCAL PROTECTION

From the intermediate screening phase this project warranted further evaluation because the economic benefits exceeded the project costs. A reevaluation was conducted. Based upon a more detailed set of design considerations a new cost estimate was prepared for the Standard Project Flood. Based on 1975 price levels, the estimated costs as shown on Table 2-13 are $9 million. Updated to reflect 1979 price levels the cost is $11,250,000 exclusive of the non-Federal responsibilities.

TABLE 2-13

REASONABLE CONTRACT ESTIMATE STD PROJECT FLOOD

PAWTUXET PROJECT - WARWICK AVENUE DIKE

JULY 1975 PRICE LEVELS

Description	Estimated Quantity	Unit	Unit Price	Estimated Amount
Preparation of Site	1	Job	L.S.	20,000
Control and Diversion of River	1	Job	L.S.	100,000
Common Excavation (138,415)	138,400	C.Y.	4.00	553,600
24" Protection Stone (22,349)	22,350	C.Y.	30.00	670,500
12" Protection Stone (2,184)	2,180	C.Y.	30.00	65,400
Protection Stone (10'wide) (13,888)	13,900	C.Y.	30.00	417,000
12" Bedding Stone (10,995)	11,000	C.Y.	30.00	330,000
Crushed Stone (10,323)	10,300	C.Y.	7.50	77,250
12" Gravel Bedding (17,173)	17,170	C.Y.	7.50	128,775
Comp. Gravel Fill (14,172)	14,170	C.Y.	7.00	99,190
Comp. Impervious Fill (35,189)	35,190	C.Y.	5.00	175,850
Comp. Random Fill (23,713)	23,710	C.Y.	4.00	94,840
Comp. Sand Fill (6,923)	6,920	C.Y.	5.00	34,615
Comp. Pervious Fill (47,753)	47,750	C.Y.	5.00	238,750
Topsoil (1,517	1,520	C.Y.	7.00	10,640
Seeding (9,102)	9,100	S.Y.	0.50	4,550
Bituminous Pavement (1,088)	1,090	S.Y.	3.50	3,815
Concrete - T Walls (5,551)	5,550	C.Y.	120.00	666,000
Concrete - L Walls (1,721)	1,720	C.Y.	120.00	206,400
Concrete - I Walls (276)	280	C.Y.	120.00	33,600
Concrete - Street Gate (348)	350	C.Y.	120.00	42,000
Concrete - Gravity Wall (668)	670	C.Y.	85.00	56,950
Concrete - Pedestrian Gate (140)	140	C.Y.	120.00	16,800
Concrete - R.R. Gate (260)	260	C.Y.	120.00	31,200
Cement (50,561)	50,560	Cwt	2.70	136,512
Reinforcing Steel (1,244,400)	1,244,400	Lb	0.40	497,760
Structural Steel - Street Gate	23,000	Lb	3.00	69,000
Structural Steel - Pedestrian Gate	7,300	Lb	3.00	21,900
Structural Steel - R.R. Gate	20,500	Lb	3.00	61,500
Steel Sheet Piling (9,383)	9,380	S.F.	8.00	75,040
8" BCCMP (sub-drain) (3,590)	3,590	L.F.	5.00	17,950
				4,957,487
TOTAL DIRECT COST				
Interior Drainage	1	Job	L.S.	334,000
Pumping Stations	2	Job	L.S.	720,000
				6,011,487
± 20% Contingencies				1,188,513
				7,200,000
25% E&D, S&A				1,800,000
TOTAL CONSTRUCTION COST				9,000,000
TOTAL CONSTRUCTION COST (UPDATED TO SEPT. 1978)				11,250,000

The project investment shown below is based on the then prevailing 6-5/8 percent interest rate for a construction period of three years, exclusive of lands and damages, a non-Federal contribution. The operation and maintenance as well as interim replacements, also a non-Federal responsibility, are shown below:

Project Investment	
Construction Costs	$11,250,000
Interest During Construction	1,118,000
Total	$12,368,000
Annual Charges	
Interest & Amortization	$821,000
Operation & Maintenance	15,000
Major Replacements	6,200
Total	$842,200

The entire grouping of benefits for the Local Protection Project as a single purpose flood control element is as shown on Table 2-14.

ELMWOOD AVENUE LOCAL PROTECTION PROJECT

The area that would receive protection from this inclosure is mainly one family residential structures with about 10 small to moderately sized commercial firms that would begin to be inundated in the range of 2 to 4 percent frequency storm event. Because of increasing urbanization in upstream areas, the frequency of flooding to this locale has increased to a point where several times a year some overbank-road flooding and measurable cellar flooding occurs. Most of the homes in the area have installed sump pumps and some have eliminated the usage of the cellar for any significant purpose. In many instances the pumps are not of sufficient size to handle the inflow of water. Recently, about every five years, significant basement-road flooding occurs, and at about a 10 to 15 year recurrence interval first floor flooding is received by homes.

Because of the projected increase in river stages due to uncontrolled increasing nonflood plain urbanization upstream, more frequent flooding can be expected with a subsequent increase in damages to both a specific flood event and to the annual losses. With the tremendous effect on the social well-being of the area's inhabitants, continued evaluation of this damage site is mandatory even with only a marginal B/C ratio.

TABLE 2-14

ANNUAL BENEFITS

VARIOUS PROTECTION SCHEMES

	Basic 1970	Hydrologic 1990	Future Hydrologic 1985-2085	Location Benefit	Economic Growth 1972-1985	Economic Growth 1985-2035	Total Economic Growth	Total Annual Benefits
Warwick Avenue Local Protection Project	$367,500	$463,200	$460,400	$27,750	$168,600	$469,500	$638,100	$1,126,300
Elmwood Avenue Local Protection Project	47,600	58,300	57,900	11,100	21,200	59,200	80,400	149,400
Big River Reservoir	405,200	552,700	548,300	--	145,700	0	145,700	694,000
Big River & Both L.P.'s Combined	696,900	910,100	903,900	38,900	207,000	585,400	792,400	1,735,200

The total estimated construction cost as of July 1975 was $2,313,000 as derived on Table 2-15, updated to 1978 conditions this is equivalent to $2,900,000 exclusive of lands and damages and other non-Federal responsibilities.

The project investment, based on 6-5/8 percent for a construction period of 2 years, and the annual charges are shown below.

Project Investment	
Construction Costs	$2,900,000
Interest During Construction	190,000
Total	$3,090,000
Annual Charges	
Interest & Amortization	$ 205,000
Operation & Maintenance	-
Major Replacements	-
	$ 205,000

The annual benefits for the Elmwood Avenue area also were determined to the same degree of detail as explained for the earlier detailed single purpose alternative. The listing of benefits for the Elmwood Avenue area is shown on Table 2-14 on page 2-45.

BULOVA LOCAL PROTECTION PROJECT

The Bulova project was evaluated in greater economic and engineering detail. Based upon the availability of more refined engineering data, it was determined that two significant modifications of the preliminary project considered in Step 3 would be required. Relocation of a portion of a warehouse would be required as a measure to provide the necessary land area for dike construction, or the use of concrete floodwalls would be required for a portion of the previously considered dike protection plan. The second modification would require major relocation of a brook. Because of the additional costs for providing these essential modifications, the project lost its previous marginal justification and was withdrawn from further consideration. The estimated cost for this project based on the more detailed engineering and design criteria is 1.92 million dollars in 1978 dollars, while the benefits also would rise due to inflation (about 30 percent). Further Federal involvement for the Bulova project is unwarranted.

BIG RIVER RESERVOIR SINGLE PURPOSE PLAN

As mentioned previously in this section the Big River Reservoir site was being studied by the State of Rhode Island for a potential water

TABLE 2-15
COST ESTIMATE
ELMWOOD AVENUE DIKE
JULY 1975 PRICE LEVELS

	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT
Preparation of Site	1	Job	L.S.	$ 20,000
Control and Diversion of River	1	Job	L.S.	5,000
Common Excavation (30,833)	30,800	C.Y.	4.00	123,200
Rockfill (Landside) (17,175)	17,200	C.Y.	10.00	172,000
Rockfill (Riverside) (34,635)	34,600	C.Y.	10.00	346,000
Crushed Stone (4,583)	4,600	C.Y.	7.50	34,500
Gravel Bedding (Landside) (12,776)	12,800	C.Y.	7.50	96,000
Gravel Bedding (Riverside) (8,596)	8,600	C.Y.	7.50	64,500
Comp. Impervious Fill (40,138)	40,200	C.Y.	5.00	201,000
Comp. Gravel Fill (5,739)	5,750	C.Y.	7.00	40,250
Comp. Random Fill (56)	60	C.Y.	4.00	240
Concrete-I Walls (404)	410	C.Y.	120.00	49,220
Cement (2,279)	2,280	Cwt	2.70	6,156
Reinforcing Steel (60,600)	60,600	Lb	0.40	24,240
Steel Sheet Piling (14,375)	14,400	S.F.	8.00	115,200
8" BCCMP (Sub Drain) (4,500)	4,500	L.F.	5.00	22,500
Interior Drainage	1	Job	L.S.	100,000
Pumping Station	1	Job	L.S.	100,000
Stop Log Barrier - Elmwood Ave.	1	Job	L.S.	10,000
TOTAL DIRECT COST				$1,529,986
w/20% Cont.				1,836,000
26% E&P, S&A				477,000
TOTAL COST				$2,313,000
TOTAL COST (UPDATED TO SEPT. 1978)				$2,900,000

supply reservoir. (It should be noted that during the plan formulation effort, this original concept was true up to January 1978. Up to that time the various protection schemes could consider the use of this potential reservoir only as an uncertain future action measure). By the addition of flood control storage equal to the equivalent of a 6" runoff from the upstream drainage area, flood stage reductions will be evident for all downstream reaches along the South Branch and the main stem Pawtuxet River. Although the stage reduction is less than 2 feet for the entire range of flood events, it is significant enough to have a substantial effect on lowering damages. The benefits are shown on Table 2-14 on page 2-45.

The final costs associated with the construction of the multiuse Big River project are highly dependent upon the first cost of the reservoir project. Several different (initial) estimates have been completed by the engineering firm designing the reservoir for the State of Rhode Island. In addition, there are several contingencies that must be implemented before determining the true value of the water supply for Big River. The main contingency is the construction of a water supply detention area in the neighboring Pawcatuck watershed. When, and if, completed the water will be pumped from this area into Big River for ultimate storage. A second problem consists of the surficial geology and the impoundment area. Geology studies are presently underway to determine the suitability of this site for water supply storage and these results may necessitate the installation of an impermeable layer to hold water in the reservoir. This cost although attributable solely to water supply will dictate the final cost of the water supply portions.

For the purpose of this report, Big River assumes that the Wood River complex will be built. Two cost estimates are shown in Tables 2-16 and 2-17. The first is the water supply reservoir with flood control storage added and the second is the estimate of only a flood control reservoir at Big River. The cost estimate for the water supply only reservoir is shown on Table 2-18.

The resultant B/C ratios for the flood control separable cost alone and the water supply reservoir only are 1.24 and 1.06 respectively. The B/C ratio for the flood control reservoir acting alone is only 0.5 to 1.0. This is not economically feasible as a single action flood control measure.

DEVELOPMENT OF DETAILED PLANS

This phase of the plan formulation efforts combined the single action measures that were considered feasible for the intermediate level. Detailed analyses were conducted on each alternative in this stage. Ten plans were evaluated. Alternatives involved various

TABLE 2-16

WATER SUPPLY AND FLOOD CONTROL RESERVOIR

COST ESTIMATE

	QUANTITY	UNIT COST	TOTAL COST
Site Preparation	1	L.S.	$5,520,000
Stream Control	-	-	512,000
Earth X-Common	264,000 CY	2.00	528,000
Earth X-Borrow	1,459,500 CY	1.80	2,592,070
Rock X	203,800 CY	6.50	1,324,700
Earth Emb. (Rolled)	1,486,900 CY	0.60	892,140
Select Gravel	99,000 CY	7.80	772,200
Rockfill Placing	255,000 CY	1.80	459,000
Concrete (Mass.)	10,200 CY	130.00	1,326,000
Concrete (Reinf.)	10,400 CY	180.00	1,872,000
Bridges Superstructure	2,670 SF	37.00	98,790
Gates & Machinery	-	-	-
Stop Logs	-	-	-
Slurry Trench Cutoff	1,186,500 SF	19.00	22,543,500
Contingency 20%			7,680,000
Cemetery Relocation	160 graves	1,200.00	192,000
Road Relocations & Reconstruction	22,000 lf	160.00	3,520,000
Utility Relocation	-	--	1,782,000
Buildings Ground & Utilities	-	--	222,000
		E & D - 9%	4,666,000
		S & A -12%	6,221,000
Land & Damages			8,985,580
TOTAL PROJECT COST			$71,700,000

Note: Based on the Big River Reservoir feasibility report these costs have been reduced.

TABLE 2-17

FLOOD CONTROL RESERVOIR
COST ESTIMATE

	QUANTITY	UNIT COST	TOTAL COST
Preparation of Site	-	-	1,550,000
Stream Control	-	-	407,000
Earth X-Common	82,000 CY	2.40	196,800
Earth X-Borrow	200,000 CY	2.20	440,000
Impervious Blanket	90,630 CY	3.20	290,000
Rock X-Open Cut	40,000 CY	10.00	400,000
Embankment (Rolled)	232,000 CY	0.90	208,800
Select Gravel	22,000 CY	8.20	180,000
Rockfill Placing	50,000 CY	2.70	135,000
Concrete, Mass.	7,600 CY	130.00	988,000
Concrete, Reinf.	4,200 CY	190.00	798,000
Bridge Superstructure	1,260 SF	40.00	50,400
Gates and Machinery	-	-	26,000
Stoplogs	320 SF	60.00	19,200
Misc. Items 10% ±			350,000
Cemetary Relocations	45 Graves	1200.00	54,000
Road Relocations	13,000 lf	166.00	2,158,000
Utility Relocations	26,000 lf	30.00	780,000
Contingencies 20% ±			1,730,000
Buildings, Grounds & Utilities			130,000
E&D - 12 %			1,292,000
S&A - 15 %			1,615,000
Lands and Damages			3,626,000

TOTAL COSTS -	$ 17,398,000
2 yrs. x 1/2 x .06125	1,065,630
Construction Cost	$ 18,463,630
Interest (.06125)	1,130,000
Amortization (.0001086)	2,010
ANNUAL CHARGE	$ 1,132,910

Using Preliminary Scrub Method

TOTAL CONSTRUCTION COSTS -	3,930,000
ANNUAL COST	452,000

TABLE 2-18

WATER SUPPLY ONLY

Crest	303.0
Surcharge	4.0
Freeboard	5.0
Elev.	312.0 Top of Dam

1. Reservoir Clearing		
Clearing 3411 acres @ 1200.00/acre	4,090,000	
Demolition of buildings 300 @ 1500.00	450,000	
20% contingencies	908,000	
		$5,448,000
2. Dam & Appurtenant Structures		
Preparation of site 46 acres @ 1900.00	87,400	
Stream Control L.S.	512,000	
Earth X-common 226,630 cy @ 2.00	453,260	
Earth X-borrow 1,298,470 cy @ 1.80	2,337,250	
Rock X 168,000 cy @ 6.50	1,092,000	
Earth Emb. (Rolled) 1,321,950 cy @ .60	793,170	
Select Gravel 85,000 cy @ 7.80	663,000	
Rockfill Placing 210,000 cy @ 1.80	378,000	
Concrete (Mass.) 10,200 cy @ 130.00	1,326,000	
Concrete (Rein.) 10,100 cy @ 180.00	1,818,000	
Bridge Superstructure 2,670 SF @ 37.00	98,790	
Gates & Machinery (2 sets reqrd)	55,000	
Stop Logs 224 SF @ 40.00	8,960	
Slurry Trench cut off 1,186,500 SF @ 19.00	22,543,960	
		$32,166,330
Misc Items 10%	3,217,000	
Contingencies 20%	6,433,000	
Total Dam and Appurtenant Structures	41,816,330	
3. Relocations		
Cemeteries 160 graves @ 1200.00	192,000	
Road Relocations and Reconstruction:		
Route #3 400 LF @ 160.00	640,000	
Division Street 9000 LF @ 160.00	1,440,000	
Harkney Hill Road 9000 LF @ 160.00	1,440,000	
Henry Brown Road 11,000 LF @ 10.00	110,000	
Utility Relocation		
Electric	346,200	
Telephone	346,200	
Contingency 20%	679,050	
		$5,193,450
4. Buildings, Grounds and Utilities	170,000	
5. Engineering and Design (8%)	4,210,000	
6. Supervision & Administration (8%)	4,210,000	
7. Lands & Damages		
Land & Improvements 4890 acres	6,800,000	
Flowage Rights	140,000	
Resettlement Costs	55,000	
Contingency 20%	1,400,000	
Total Lands & Damages		8,395,000
Total Project		$69,443,000

combinations and design levels. One of the alternatives consisted of the No Action plan. All alternatives assumed that flood insurance would be available for the various communities within the watershed. This would help eliminate future flood losses to new developments.

From the previous iterations, it was apparent that only the main stem Zones 4-8 would be the subject of any further detailed studies for any corrective measures, other than a potential reservoir site at Big River. There was not any single action corrective measure that passed the intermediate level of screening for the many tributary streams, other than that previously mentioned. The remainder of the planning process dealt with the derivation of detailed costs, benefits, environmental studies and evaluation of various flood control systems combining corrective, corrective nonstructural and regulatory measures.

The major components of the alternative plans are described in the following paragraphs.

Natick Diversion Options - As previously evaluated, the Natick Diversion was evaluated for various schemes having inside tunnel diameters ranging from 20 to 33 feet and respective flow diversion rates varying from 5,000 to 18,000 cfs. The 30-foot diameter tunnel was the largest sized tunnel that appeared to be economically feasible. Also justified as a single action measure was a local protective works. A third measure was carried forth with minimal channel modification because of the social disruptions that the continual flooding has had on the area. The final measure involved various considerations of Big River Reservoir, initial economic evaluation of these projects in the intermediate screening had been developed on the basis of engineering judgment and basic assumptions without the benefit of highly specific engineering data, such as subsurface explorations, field surveys and application of various tunnel technologies, and environmental studies. As it became evident that the Natick Diversion and two local protective works would constitute key considerations in a basin management plan, more detailed engineering studies were made so that the combining of measures could be fully evaluated.

A comparison showing the effectiveness of a 30-foot diameter tunnel with a 21-foot diameter tunnel at the Natick Dam is noted below in terms of flood stage reduction, in feet, at a Standard Project Flood event for each of the main stem zones following implementation of a diversion project:

FLOOD STAGE REDUCTION BY ZONES

DIVERSION DIAMETER	4	5	6	7	8
			(in feet)		
30 Feet	8.5	8.0	8.5	4.5	3.0
21 Feet	3.0	3.0	3.5	2.0	1.5

This comparison demonstrates the effects of the Natick Diversion upon downstream main stem reaches, in that the larger the tunnel diameter, the greater the flood stage reduction and protection afforded by it.

As the tunnel diameter is increased, the residual damages downstream decrease. Residual losses are minor for Zones 4, 5 and 6 but are very significant (although still reduced by over 50 percent) for Zones 7 and 8. The losses are independent of tunnel size. However the smaller the tunnel the greater the residual damage.

Natick Diversion Pumped Storage Option - During the evaluation of the Natick Diversion structure, a supplemental study was made concerning possible use of the proposed tunnel as part of a pumped storage power project. Instead of a straight alignment, the tunnel would have a dogleg to the vicinity of Bald Hill (summit elevation 242 feet) and would require an additional length of 1,000 feet. The closed-system power facilities would include an 81-million cubic foot capacity upper reservoir near the hill summit, a penstock connecting with the tunnel and an underground powerhouse. The tunnel would serve as the lower reservoir, with control gates at the outlet to prevent salt water from entering the system. Additional head could be developed by tunnel deepening. Various installations were evaluated, ranging from 22,000 to 57,000 kilowatt capacity, with average net head varying from 370 to 570 feet, respectively. Preliminary study indicated that peaking power generation, based on a 10 percent load factor, would not be economically justified as a separate cost in connection with the flood control features of the project. In addition the separable cost of the power facilities also did not meet the test of being less than the least alternative cost. Because a gas turbine installation would represent a less expensive alternative, no further evaluation was made of the Natick Diversion pumped storage option.

Floodproofing Options - During the field investigations of floodproofing measures as a single action measure in the lower basin, the study team also investigated the prospects for justification of lesser degrees of floodproofing (i.e., protection against lower levels of flooding) in the event that flood stage reductions could be accomplished by implementation of Natick Diversion and complemented by the then future action provision of floodwater storage at Big River Reservoir. It was determined that the Natick Diversion plus

floodproofing at lower levels of flooding than the 100-year was not economically justified incrementally. Therefore, no further Federal evaluation of floodproofing was warranted as part of a combination of measures.

Main Stem Alternatives - All alternatives would assume the availability of the National Flood Insurance Program as an effective land use control measure and an effective measure for reimbursement of structural flood losses and contents. All alternatives except the No Action plan (Alternative F) would include possible additional regulatory measures, should the individual communities so desire additional land use controls, plus the possible implementation of future action measures along the North and South Branches, which collectively could reduce existing and potential flood problems along the main stem. A summary of the economic analysis for each alternative, including project costs, is presented in the Main Report.

Alternative A - This alternative would consist of the Natick Diversion, with a 30-foot diameter tunnel. With Natick Diversion as the only structural component, substantial flood loss reductions would be realized in the main stem zones and in the tributary zones affected by backwater conditions. Average annual losses along the main stem would be reduced by the diversion to an average annual loss slightly more than $800,000.

Implementation of the 30′ diversion reduces the number of ownerships affected by a 100-year flood event from 471 to 266, and for an SPF event from 1,856 to 959. In addition, the diversion also provides a substantial reduction in water depths in the 266 ownerships still subject to residual flooding by a 100-year flood event. In that group the following residual flooding would be experienced: 6 to 11 feet in 94 ownerships, 3 to 6 feet in 81 ownerships and less than 3 feet in 91 ownerships. For the 100-year event, four ownerships would (theoretically) have to be relocated, of which one is located in Warwick, three in Cranston and none in West Warwick. In the group of 959 ownerships subject to flooding by the SPF event after the diversion, the following residual flooding would be experienced: excess of 11 feet in 316 ownerships, 6 to 11 feet in 113 ownerships, 3 to 6 feet in 180 ownerships and less than 3 feet in 350 ownerships.

A component of this alternative would be the future action elements consisting of flood control storage at Big River Reservoir to be built and designed by others and the regulation/management of Scituate Reservoir. When combined with the 30′ diameter Natick Diversion to act as a system the proposal would be economically justified due to the low separable costs of the flood control element. The additional net benefits along the South Branch and the main stem would result in a system of B/C ratios of 1.03 to 1. The

additional flood stage reduction at events ranging from about a 100-year event down to the common yearly type flood would remain the same as the diversion is capable of discharging the floodwaters. However, at events rarer than the one percent flood stage, reduction of one half foot up to one foot is possible depending upon the zone and the flood event.

Alternative B - This alternative would consist of Natick Diversion with a 30' diameter tunnel and the Warwick Avenue and Elmwood Avenue local protection projects. From the various local protection measures evaluated as single action measures a plan evolved that would provide local protection measures for extreme northeastern Warwick extending from the lower limits of Zone 6 and including all damaged portions of Zones 7 and 8. A series of dikes, floodwalls and other structures would provide full protection to the SPF event as modified by Natick Diversion, to the residential-commercial area in the vicinity of Elmwood Avenue (U.S. 1) and the Warwick Industrial park and adjacent residential-commercial area in the vicinity of Warwick Avenue (RI 117).

Provision of the Natick Diversion and the Elmwood Avenue-Warwick Avenue protective measures would reduce average annual losses in the lower basin to approximately $200,000 with the 30-foot diameter tunnel project. With the 30-foot diameter diversion tunnel and the Warwick protective measures, most of the residual losses would occur within the Cranston portions of Zones 4B, 6, 7 and 8, but protective measures for these Cranston areas proved not to be economically justified. The remaining losses in Warwick Zones 4, 5 and 6 and the West Warwick portion of Zone 4 would be minimal following reductions by the Natick Diversion.

Local protection measures for the Bulova Watch Company industrial complex in Zone 5, which had been determined to be marginally justified as a single action measure were reconsidered in combination with the Natick Diversion. With the 30-foot diameter diversion tunnel, flood stages would be substantially reduced so that flood damages at the Bulova complex would be minimal. At the 100-year flood level only the lower floor of the main office building would be subject to flooding. Under such conditions, the use of sandbags at the building entrances and adequate interior pumping facilities could eliminate interior flood losses. Therefore, it was determined that local protection measures acting in conjunction with Natick Diversion would not be economically justified at the Bulova industrial complex.

As summarized in Table 2-19, implementation of Alternate B (Natick Diversion with 30-foot diameter tunnel and Warwick Avenue and Elmwood Avenue local protection) would reduce the number of ownerships affected by the 100-year flood level from 471 to 148.

TABLE 2-19
OWNERSHIPS SUBJECT TO FLOODING
FOLLOWING PROVISION OF NATICK DIVERSION
AND WARWICK LOCAL PROTECTION
(Zones 4, 5, 6, 7, 8, 4B, 6B and 7B)

Community/ Category	100-Year Flood Natural Conditions	100-Year Flood Following Alternative C-1	Standard Project Flood Natural Conditions	Standard Project Flood Following Alternative C-1
WARWICK				
Commercial	21	1	44	11
Industrial	13	1	19	6
Residential	146	0	570	16
Public	2	1	2	2
Schools	0	0	0	0
Others	3	0	4	4
Sub-Total	185	3	639	39
CRANSTON				
Commercial	11	10	27	17
Industrial	6	4	16	7
Residential	206	122	1,083	613
Public	2	2	8	6
Schools	1	1	2	2
Other	2	1	5	4
Sub-Total	228	140	1,141	649
WEST WARWICK				
Commercial	10	1	11	10
Industrial	4	1	5	4
Residential	41	2	53	48
Public	1	1	1	1
Schools	1	0	3	1
Others	1	0	3	1
Sub-Total	58	5	76	65
Totals	471	148	1,856	753

A component of this alternative would be the future action elements consisting of flood control storage at Big River Reservoir and the regulation/management of Scituate Reservoir. When combined with the above system, a B/C ratio of slightly above unity would be realized.

Alternative C - This alternative would consist of Natick Diversion with a 21-foot diameter tunnel and the Warwick Avenue-Elmwood Avenue local protection projects. The series of dikes, floodwalls and other structures are basically the same as the previous alternative. However, the walls and dikes are several feet higher than those considered in Alternative B as the diversion cannot divert as much floodwater into Apponaug Cove. Both local protection projects were justified as single action measures in the intermediate level of detail and combined with the single purpose Natick Diversion with a 21-foot diameter discharge tunnel.

Implementation of this alternative would reduce average annual losses in the lower basin to approximately $520,000.

Local protection measures for the Bulova Watch Company industrial complex in Zone 5, which had been determined to be marginally justified as a single action measure in Step 3, were reconsidered in combination with the Natick Diversion. With the 21-foot tunnel as with the 30-foot diameter diversion tunnel, flood stage would be substantially reduced so that flood damages at the Bulova complex would be minimal. At the 100-year flood level only the lower floor of the main office building would be subject to flooding. Under such conditions, the use of sandbags at the building entrances and adequate interior pumping facilities could eliminate interior flood losses. Therefore, it was determined that local protection measures acting in conjunction with Natick Diversion would not be economically justified at the Bulova industrial complex. No other reevaluated local protection projects were considered due to the high reduction in losses afforded by the diversion.

A component of this alternative would be the future action elements consisting of flood control storage at Big River Reservoir and the regulation/management of Scituate Reservoir. When combined with the above system, a B/C ratio of 1.25 would be realized.

Alternative D - This alternative would consist of the same two local protection projects discussed previously--the Warwick Avenue and the Elmwood Avenue local protection projects.

COMBINED COSTS - LOCAL PROTECTION PROJECTS
WARWICK AVENUE AND ELMWOOD AVENUE
(Based on 1978 Prices, 6-5/8 percent interest)

PROJECT INVESTMENT	
Construction Costs	$14,150,000
Interest During Construction	1,308,000
Total	$15,458,000
ANNUAL CHARGES	
Interest & Amortization	$ 1,026,000
Operation & Maintenance	15,000
Major Replacements	6,200
	$ 1,047,200

The protective measures evaluated for the combined Elmwood Avenue-Warwick Avenue area would protect the same area of Warwick (Zones 7, 8 and part of Zone 6) as considered in the intermediate screening level. However, the project was evaluated in greater economic and engineering data. Protection of this Warwick area to the SPF level was determined to be economically justified. The Warwick local protection project would provide a benefit of about $1,950,000. While the local protection project for comparative purposes would protect 150 ownerships that are subject to flooding at the 100-year flood level, it is standard practice to design Corps local protection projects in urban areas to the SPF level to avoid the false sense of security that could result from lower levels of protection. In all, the Warwick local protection project would protect 450 ownerships; 9 industrial, 21 commercial and 420 residential.

For comparative purposes only, at the occurrence of a 100-year flood event, river stages would be 3 to 6 feet higher than those experienced in the March 1968 flood, and 7 to 15 feet higher than normal river stages. Under SPF conditions, river stages would be 11 to 15 feet higher than those experienced in the March 1968 flood, and 13 to 20 feet higher than normal river stages.

The estimated costs for the projects, evaluated as a system were $1,130,000 on an annual basis. The overall systems B/C ratio is 1.72.

Alternative E - This alternative consists of the provision of flood control storage equivalent to 6 inches of runoff at the proposed Big River Water Supply Reservoir. The plan would also consist of a management/regulation of both Scituate and Big River Reservoir to help reduce flood stages by allowing some floodwater storage at Scituate without losing any water supply potential. As Big River would be designed for flood control, management of this reservoir is less critical.

Benefits for the flood control increment at Big River are realized in all downstream zones from the confluence of Big River and the South Branch down to and including Zone 8. The total annual benefits for all zones combined amounts to about $500,000 excluding any growth.

The project, as mentioned previously, is not justified as a single purpose flood control dam but when considered as a component of the major water supply purpose is justified for flood control when cost-allocated. The overall B/C ratio is 1.39.

Alternative F - This alternative would consist of the No Action program--one that local interests would implement in the absence of a corrective Federal assistance program. It is assumed that local interests would institute a program for controlling growth within the 100-year flood plains, at least the minimum zoning controls required for eligibility in the National Flood Insurance Program. The plan would be equally applicable to both main stem zones, and all major tributary streams.

As this alternative would exclude the consideration of structural components, reduction in flood stages for alleviating damages in flood prone areas would be unattainable. Some intensification of flood problems could be expected in varying degrees because of continuing urbanization within the basin with the program. If the No Action alternative is not implemented as a minimum program, flood problems can be expected to magnify over the years.

This alternative includes the only means available for compensating losses due to flooding, through municipal and individual participation in the National Flood Insurance Program. However, flood losses would be only partially covered as there are no existing provisions for compensating policyholders for nonphysical losses, such as expenses for lodging during dwelling rehabilitations or loss of income or profit while a commercial or manufacturing firm is temporarily closed. In addition, the uninsured would receive no monetary compensation; such a condition could result if all municipalities do not participate in the National Flood Insurance Program, which includes the requirement that flood plain zoning to the 100-year event be instituted. Future flood losses along the main stem alone would far exceed $5 million annually, including new development that could be expected during the next 25 years at a conservative growth rate. These estimated losses to potential growth development with the flood plains, in excess of $2 million annually, are based on analysis and projections of past development trends in the flood plains.

Alternative G - This alternative consisted of the 21-foot diameter Natick Diversion tunnel and the Warwick Avenue local protection project. Alternative G is the same as Alternative C except that the Elmwood Avenue local protective works has been dropped from consideration. With this protection scheme, the estimated costs are \$3,558,000 and the total benefits or damages prevented are equal to \$4,545,000. Thus the overall B/C ratio is equal to about 1.28 to 1.

Conclusions - The above seven alternatives were presented for comment at a late stage public meeting held 14 October 1976. A draft feasibility report and EIS were prepared and distributed to the public prior to the meeting. Because of tremendous unexpected opposition to the then selected plan, Alternative B above, some reformulation and a new report was necessitated. The reasons for the opposition were twofold; the alleged high tunnel project cost and the potential environmental harm to Apponaug Cove-Greenwich Bay during a major diversion event. At plan formulation public meetings in May 1975 during which time the various considered alternatives were discussed, the cost of the 300-foot diameter tunnel was cited as ranging between \$29 to \$42 million depending upon the method of construction and the quality of rock encountered. These costs were also exclusive of lands and damages. The lower cost assumed that the mole method of construction could be used, a 30-foot diameter mole machine was available, the entire length of tunnel construction was adaptable to the mole method and that the tunnel could remain unlined. The \$42 million figure considered drilling and blasting with a thin shell concrete lining the entire length of the tunnel. At that stage of analyses, the deep rock borings along the tunnel's proposed route had not yet been started. In the interim report prepared for the October 1976 public meeting, \$49 million was recorded as being the cost for the diversion tunnel. The opposition claimed that the costs have risen unexpectedly \$20 million in a 1-1/2 year time frame. Cited costs for the tunnel at the late stage meeting were trying to establish that even under the least likely-most costly construction method, the project was still economically feasible. The detailed geology analyses have subsequently shown that with the exception of less than 25 percent of the tunnel's length the mole method--unlined tunnel could be used. However, the uncertainty of the actual mole method of construction and its availability necessitated this Division reporting the higher cost, one that would in all likelihood be reduced in the final detailed design stages, if the project were to proceed that far. The \$49 million figure represents only cost inflation from the 1975 figures and inclusion of lands and damages.

The section on environmental effects of the diversion on Page 4-29 represents the most accurate summation of environmental degradation that is available. The basis of these facts is the result of

computer simulation studies performed by a most knowledgeable and reputable architect engineering firm that specializes in this type of work. To our belief the estimates of concentration and durations represents the worst possible situation. All contradictory statements expressed at the public meeting were unsupported by factual data. Although the diversion was overwhelmingly opposed by virtually all the speakers at the public meeting and subsequently dropped from the selected plan, it is still our position that the environmental harm to marine environment in Apponaug Cove and Greenwich Bay is minimal. Also at the public meeting little support was expressed for the Warwick Avenue project and only local support for the Elmwood Avenue project.

In the next several months considerable discussions at meetings and workshops were held with State and local officials to try to find out what could be done to arrive at a publicly acceptable plan and still provide a high degree of flood relief. The discussions included the obvious--termination of the study due to lack of support. However, reassurances from State elected officials, as well as State and local Governments mandated continuation of the study.

At that time it also became evident that the State of Rhode Island was now interested in having the Corps of Engineers as the planner-designer of the Big River Reservoir project, and if justified and environmentally acceptable, construct the complex. This then necessitated a more accurate hydrological determination as to effects downstream created by the Big River Reservoir impoundment. (All initial studies used only preliminary approximations). Although detailed answers were not available and in order to expedite as much as possible the already delayed completion of the report, a final late stage public meeting was held on 9 May 1977.

At that meeting the plan discussed consisted of a multipurpose Big River Reservoir project as the main element of the plan.and the two local protection measures downstream (Elmwood Avenue and Warwick Avenue projects) similar to Plan D. The meeting informed the public of the new compromise plan but also mentioned that reevaluation was necessary to determine the economics of the plan, as well as to evaluate costs due to the new elevations brought about by the main element, Big River.

Although verbal acceptance of the State's interest in the Corps pursuing the Big River Reservoir studies had been received, the additional delays encountered and additional costs made it necessary for this office to have in hand a letter signed by the Governor of Rhode Island before any large scale study or expenditure or written report was made.. The letter was finally received on 9 January 1978 requesting the Corps to study Big River.

It became apparent that the preliminary reductions afforded by Big River Reservoir needed minor revisions due to the interaction with the frequency of tidal storms. Although reductions of 2.5 feet at a 100-year riverine flood are possible with Big River's flood control element, when a 100-year tide is considered the net reductions of only one foot are predicted. With this, an increased height for the local protection projects downstream had to be considered over and above those proposed with the Diversion schemes. These dikes and walls were from three to five feet higher than with the Natick Diversion or one to two feet higher than originally considered with the original Big River concept. The heights of the single purpose flood control system of walls and dikes remained the same, but due to the detailed soil analyses now in hand, a significantly larger dike cross-section was necessary as well as the addition of two extra feet of free board to account for settling at Elmwood Avenue. A description of the soil conditions is described on Page 4-52.

Complete reevaluation of the Elmwood Avenue project became necessary to see if it was economically justified.

Alternative H - Two new plans were formulated. The first is fundamentally the same as Plan D with the exception that the Big River Reservoir will be planned by the Corps of Engineers and if found feasible and environmentally acceptable will also be designed and constructed. As the design of the reservoir and its operation would be governed by the Corps of Engineers, flood control storages can be carefully regulated and/or controlled. It was then necessary to determine the stage reductions that would be evident due to the modifying effect of Big River. The results of the hydrologic analysis proved to be very similar to the initial assumptions used for Plan E.

However, as noted previously, one important change became evident. Because of the foundations and materials investigations and the relatively small reduction afforded to the LPP's in comparison to the diversion, the heights of the two local protection measures would have to increase. The overall effect on the Warwick Avenue local protection would remain about the same as with the levels considered under Plan D. The significant change occurs in the Elmwood area where the reanalysis indicated that riverside berms in the order of 20 feet wide will be required to stabilize the dike. In addition, the reductions afforded under the initial scheme of Plan D were not as great as with the recalculated values mainly because of the tidal influence. The costs of the interior drainage facilities also increased significantly. The cost estimates for the two local protection projects as shown in Table 2-20. The annual charges for the two local protection projects are shown on the following tabulation.

TABLE 2-20
ELMWOOD AVENUE AND WARWICK AVENUE LOCAL PROTECTION

	Elmwood Avenue	Warwick Avenue	Total Quantity	Unit Cost	Total
Preparation of Site	1	1	2	LS	[illegible]
Control & Diversion of Water	1	1	2	LS	[illegible]5,000
Common Excavation	42,000	139,500	181,500	4.70	85[illegible]
24" Protection Stone	-	21,950	24,950	35.00	768,250
12" Protection Stone	-	2,210	2,210	35.00	77,350
Protection Stone	24,000	13,900	37,900	35.00	1,326,000
12" Bedding Stone	-	10,810	10,810	35.00	378,[illegible]
Crushed Stone	10,000	10,400	20,400	9.00	183,600
12" Gravel Bedding	17,000	17,480	34,480	9.00	310,320
Compacted Gravel Fill	9,000	14,530	23,530	8.00	188,240
Compacted Impervious Fill	41,000	33,400	74,400	6.00	446,400
Compacted Random Fill	-	25,100	25,100	4.70	117,970
Compacted Sand Fill	3,000	6,930	9,930	6.00	59,580
Compacted Pervious Fill	75,000	39,000	114,000	6.00	684,000
Topsoil	2,000	1,320	3,320	8.00	26,565
Seeding	11,000	7,780	18,780	0.60	11,268
Bituminous Pavement	-	1,100	1,100	4.00	4,400
Concrete T walls	3,300	5,410	8,710	140.00	1,219,400
Concrete L walls	-	1,700	1,700	140.00	238,000
Concrete I walls	200	250	450	140.00	63,000
Concrete Gravity wall	-	650	650	100.00	65,000
Concrete Gate Structures	600	450	1,050	140.00	147,000
Cement	27,000	47,600	74,600	3.00	223,800
Reinforcing Steel	602,000	1,170,000	1,772,000	.50	886,000
Steel Sheet Piling	8,000	8,160	16,160	9.50	153,520
Structural Steel Gates	-	23,250	23,250	3.50	81,375
8" BCCMP	5,000	3,590	8,590	6.00	51,540
Stop Log Barrier	-	1	1	LS	15,000
Street Gate	1	-	1	LS	75,000
Interior Drainage	1	1	2	LS	507,000
Pumping Station	1	2	3	LS	1,582,000
Pressure Conduit	1	-	1	LS	115,000
					$11,0[illegible]
		20% contingencies			2,206,527
					$13,250,000
		E & D - 14.0%			1,855,000
		S & A - 9.0%			1,195,000
					$16,500,000

Total with Lands and Damages and Updated to September 1978 Price Level $18,100,000

	$18,100,000
Interest during construction	1,800,000
Construction Cost	$19,900,000
Interest (.06625)	1,318,400
Amortization .0001086	2,200
Annual Charge	$ 1,320,600

(As a result of a workshop meeting held on 3 March 1979, after the January 1979 flood, a new damage survey was conducted for all homes in the Norwood-Belmont area as the residents felt that damages were actually much higher than previously estimated. All homes in this area were surveyed. One area resident has been out of her home since January 1978 when the localized flooding completely inundated her cellar and approached the first floor. The house was almost ready for occupancy in January 1979. The entire heating plant and utility room was relocated to above the first floor in a separate room. However, the January 1979 flood levels exceeded the height of the raised room. As of June 1979, she had not yet moved back into her home due to the extreme heavy losses she received. This recent survey shows a total annual loss of $381,380 including the commercial establishments. The benefits remaining after the reduction in stages afforded by Big River are $284,160. Although the benefits are $130,000 higher than previously reported, almost 50 percent, the B/C ratio for the Elmwood Avenue portion would be $284,000 divided by the projects annual change of $550,000 or a B/C of 0.52.)

Thus the total annual charges for the flood control elements of this scheme is $1,772,600 when the annual charge for Big River Reservoir is added. The average annual benefits for this alternative are shown on Table 2-14 on page 2-45. Although the resultant systems B/C ratio is 1.07 to 1.0, the Elmwood Avenue area in Warwick would cost, at a minimum, $6 million with lands and damages updated to present figures. As the protected area is mainly residential homes, the level of protection must approach a Standard Project Flood. At that level there are approximately 85 homes and 10 commercial firms that would receive damages. At the 100-year event 70 homes and 8 commercial concerns would receive damages. Only one of these commercial firms losses are significant, but in terms of annual damages are relatively minor. Considering the high cost to protect mainly residential structures, the average home would cost in excess of $75,000 each to protect. Few of the homes in the area, even with the maximum relocation assistance provisions added on, are worth the cited amount. Even though the area warrants some form of protection measures a local protection project would far exceed the costs even with potential environmental and social trade-offs. Thus any further consideration of a local protection project for Elmwood Avenue area based on the updated costs cannot be considered.

Alternative I - The second plan evolving from the reformulation consists of the multiuse Big River Reservoir, the Warwick Avenue local protection and a proposal, called the Norwood Land Bank, whereby the most flood prone homes in the Elmwood Avenue area would be purchased by Federal interests. The same nonstructural alternatives considered with all the previous plans would also be applicable to this scheme. The evaluations of the Warwick Avenue protection would be identical to those considered under the previous alternative. The difference is that the consideration for a local protection project for Elmwood Avenue has been replaced by a proposal for outright purchase of 40 to 54 homes. As with the previous alternative, Big River would be planned, designed, and if economically justified and environmentally acceptable, built by the Corps of Engineers.

Prior to the 3 March 1979 workshop meeting, residents of the Norwood area and Warwick officials had not indicated any support of a potential acquisition program. After suffering flood damages in both 1978 and 1979 and facing the reality that flooding would always be a threat, residents' support of an acquisition program grew. A petition (see Appendix 3) dated 12 March 1979, in support of the acquisition program, was signed and submitted by many of the residents of Norwood area of Warwick.

The benefits attributed to the Warwick Avenue local protection and Big River Reservoir are essentially the same as has been calculated under the previous alternatives. The benefits for the Norwood Land Bank consist of those allowable using ER 1105-2-353. The annual benefits are then converted to a present worth value using a fifty year life and the prevailing interest rate of 6-7/8 percent. The benefits are only considered for events up to a 0.5 percent natural event, approximately equal to a 1.0 percent event after modification by Big River Reservoir's flood storage. The total systems benefits are equal to $1,833,000 as shown below.

Benefits to Big River	$ 725,000
Benefits to Warwick Avenue	$ 950,000
Benefits to Norwood Land Bank	$ 158,000
	$1,833,000

The total annual cost for the protection system is $1,315,000. Thus, the total B/C ratio is 1.39 to 1.0.

Alternative J - Plan J will be referred to as the nonstructural plan. Nonstructural measures include floodproofing, relocation, and regulatory measures to minimize flood loss. As regulatory and future action measures are included in previous plans, floodproofing and relocation will be addressed here.

Floodproofing consists of those adjustments to structures which are designed or adapted primarily to reduce flood damages. These adjustments usually consist of barriers on windows and doors and a watertight membrane surrounding interior walls. Many other floodproofing schemes are also possible. Relocation is required when water exceeds the limits of the floodproofing.

Through initial screening it was determined that flood problems with Zones 1, 2, 3, 4A and 7A were minimal and so no further evaluation was required in these zones. Therefore, analysis was concentrated in Zones 4, 5, 6, 7 and 8.

A computer program was derived to provide an initial screening of the residential structures. The damage figures used in the program were based on past damage surveys performed by this Division for various types of homes, and the depth damage curves developed by the Federal Insurance Administration.

It is evident from the figures shown in Table III-2 where the B/C ratios for the 100-year and SPF are .10 and .04 respectively, that this alternative as a total system is not economically feasible. While it would allow portions of riverbank to be converted to a greenbelt area, the social ramificatons would be significant as about 65 homes would have to be either raised or relocated at a 100-year event. In addition, 13 industrial and commercial establishments would have to be relocated, resulting in the direct loss of over 100 jobs. A large increase in taxes would also be necessary to offset the new vacant lands. At the SPF analysis, although more theoretical, the losses are much more significant. Table III-1 lists these relocations by major land use category.

Current regulations and review requirements necessitate the presentation of a nonstructural plan among the final alternative plans. The data used for this plan is shown on Pages 2-26 through 2-30. The governing regulation for determining benefits on nonstructural measures for relocations is contained in ER 1105-2-353. Most of the traditional type annual damages cannot be claimed as a benefit if either relocation or evacuation is planned. The only allowable means consists of determining the net income earned by activities occupying the flood plain with the project plus that portion of the flood damages reduced by the project which is not borne by the without-project flood plain occupants.

Structures such as Ciba-Geigy, the Warwick Mall, the Warwick Industrial Park, Bulova, the Pontiac Print Works Building and the Jefferson Avenue Industrial Park cannot realistically be either floodproofed or relocated. Most of these buildings are slabs on grade type of construction with concrete block wall construction and

extensive use of glass fronts/windows. With the heights of water to be encountered the block walls and/or glass cannot be floodproofed necessitating relocation according to the intent of the regulations. At the Ciba-Geigy complex an additional fallacy of the floodproofing requirements is evident. Many of the first floors, as well as subfloors are inundated for the complex housing about twenty plus major structures. Most range in size between six to ten stories. They presently need expansion for increased production. However, they do not have any available land to expand upon. If they were forced to eliminate usage of the flood damaged floors, they could conceivably move elsewhere.

The firms and areas mentioned in the preceding paragraphs constitute over 90 percent of the existing flood damages. Summarizing, it is neither logical, practical nor economically feasible to floodproof or relocate these elements. However, in compliance with current requirements the nonstructural plan is included in the System Of Accounts. As is evident, the plan falls far short of the required B/C criteria necessary for project implementation. Thus, consideration of this measure cannot be recommended for Federal involvement.

DISPLAY OF ALTERNATIVE PLAN EFFECTS

SYSTEM OF ACCOUNTS

This phase of the analysis is the graphic presentation of the System of Accounts for the nine alternatives which warranted further consideration as the result of previous iterations. The System of Accounts (as required by "Principles and Standards for Planning Water and Related Land Resources," published in September 1973 by the Water Resources Council, and ER 1105-2-921 "Feasibility Reports: System of Accounts") reflects the overall beneficial and adverse effects of the selected alternatives. This summary of accounts is shown in Table 2-21. Effects can be readily discerned, and trade-offs between alternative plans compared. This is an integral part of the planning process leading to the selection of an alternative plan that best meets the goals and objectives of National Economic Development (NED), Environmental Quality (EQ), Social Well-Being (SWB), and Regional Development(RD).

The System of Accounts (SA) displays information concerning the geographic regions in which a significant portion of any beneficial or adverse impacts would occur. The following paragraphs define the various regions analyzed.

Within the Watershed - This constitutes the entire drainage area within the Pawtuxet River Basin. The watershed consists of portions

of 13 municipalities all located within Rhode Island. This area excludes the Apponaug Cove-Greenwich Bay areas as they are located outside the Pawtuxet River watershed.

Within the Rest of the Standard Metropolitan Statistical Area (SMSA)

In some instances significant impacts occur outside the watershed. This is the case for Alternatives A, B, C, & G which involve diverting floodwaters into the Apponaug Cove-Greenwich Bay areas, and for other studies involving interbasin transfers of power, water, or water pollutants, and for navigation studies. Significant impacts on such areas are likely to occur primarily as a result of large scale plans, either individually or as part of a system. In this study, the SMSA is the Providence-Pawtucket-Warwick area, which includes 23 Rhode Island cities and towns, plus 10 contiguous Massachusetts cities and towns.

Within the Rest of the Nation - The Principles and Standards (P&S) specify components of accounts which were considered in filling out the SA. Only components to which a significant contribution occurs are displayed. Subcategorization of the components displayed is used to further specify the source and nature of the contribution.

National Economic Development (NED) - The NED account reflects increases in the nation's productive output, an output which is partly reflected in a national product and income accounting framework designed to measure the continuing flows of goods and services into direct consumption or investment. For the NED account, flood control benefits are shown for the flood plain of Zones 4 through 8. This account is filled out in dollar terms. Benefits and associated costs are expressed as average annual equivalent basis using appropriate periods of analysis and the prevailing discount rate. Price levels for this display item are as of June 1976.

Environmental Quality (EQ) - The environmental objective is enhanced by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems in the area under study here and elsewhere in the nation. This objective reflects society's concern and emphasis for the natural environment and its maintenance and enhancement as a source of present enjoyment and a heritage for future generations. This account, along with the two accounts immediately following, have footnotes that depict specific impacts.

Social Well-Being (SWB) - This account includes most of the benefits traditionally termed intangible under existing practice.

Regional Development (RD) - This account includes impacts of the proposed plan upon the impacts and in terms of resources displaced or better used in the event that the plan is implemented. Other examples are the number and types of jobs gained or lost due to the action, the effects that the action has on distribution of population, or losses or gains in output resulting from external diseconomies within the relevant regions. If a direct monetary economic benefit or loss is attributable to the action, it is included under the heading National Economic Development.

Nomenclature - Footnotes used for the System of Accounts analysis are as follows:

CODE	MEANING
	General
YES	Effect occurs in region shown
NO	Effect does not occur in the region
NA	Effect is not applicable to the region
NQ	Effect has not been quantified
NE	Effect has not been evaluated
*	Effect is specifically designated in Section 122 of Public Law 91-611 as one which must be identified and evaluated
	Timing of Impact
1	Designates that the impact is expected to occur prior to or during plan implementation
2	Designates that the impact is estimated to occur in 15 years or less after implementation of the plan
3	Designates that the impact is estimated to occur later than 15 years after the implementation of the plan
	Uncertainty
4	Designates that the level of uncertainty associated with an impact is greater than 50 percent
5	Designates an uncertainty range of 10-50 percent
6	Designates an uncertainty range of 0-10 percent, thus suggesting that the impact is virtually certain
	Double Classification
7	Designates that the SWB, EQ, or RD account item analyzed has been fully monetized and counted as an NED beneficial or adverse contribution
8	Designates that the SWB, EQ, or RD account item analyzed has been partially monetized

	Actual or Potential Effect
9	Designates that the contribution would likely occur without any action by any entity other than the proposed implementing agency, or the required action is extremely likely to occur through the economic or natural physical systems
10	Designates that the achievement of the beneficial contribution requires positive Governmental action by another agency, other than cost sharing. The adverse contribution associated with this action would likely be prevented by Government action
11	Used when coordination indicates that the action required by other agencies would not be forthcoming

TABLE 2-21
SYSTEM OF ACCOUNTS
PLANS A, B, & C

		PLAN A			PLAN [illegible]	
		NATICK DIVERSION - 30' DIAMETER TUNNEL			NATICK DIVERSION AND WARWICK LOCAL PRO[illegible]	
		LOCATION OF IMPACTS			LOCATION OF [illegible]	
ACCOUNTS	Footnotes	Within the Watershed	Within the Rest of the SMSA	Within the Rest of the Nation	Within the Watershed	Within the [illegible]
1. National Economic Development						
Beneficial Impacts						
Value of Increased Outputs of Goods and Services						
Flood Control Benefits		3,233,800			[illegible]	
Value of Output from use of Unemployed, or Underemployed Resources in Construction or Installation						
ARA Benefits		808,200		[illegible]	[illegible]	
Total NED Benefits		[illegible]		[illegible]	[illegible]	
Adverse Impacts						
Total Project Costs		[illegible],650,000			[illegible]	
B/C RATIO		0.87			[illegible]	
NET NED BENEFITS				[illegible]		
2. Environmental Quality						
Wetlands Gained or Lost (± Acre)	1,6,8,9	No	No	No	No	No
Natural Channel Bottom lost (Acres)	1,6,8,9	[illegible]	No	No	[illegible]	No
Improved Channel Bottom Gained (Acres)	1,6,8,9	+2	No	No	+2	No
Floodway Gained or Lost (± Acres)	1,6,8,9	242	No	No	+472	No
Flood Fringe Gained or Lost (± Acres)	1,6,8,9	640	No	No	+770	No
Dredged Material to be Spoiled (cy)	1,6,7,9	No	14,500	No	No	14,500
Amount of Rock to be Spoiled (cy)	1,6,7,9	300,300	No	No	300,300	No
Effect on Marine Flora & Fauna		NA	See Table 2-22	No	NA	See Table [illegible]
Effect on Water Quality to Pawtuxet River*	2,3,6	3 Sewage Treatment Plants Remain Operative During Floods Positive	Reduced Pollutional Load to Providence River Slightly Positive	Negligible	[illegible] Sewage Treatment Plants Remain Operative During Floods - Positive	Reduces P[illegible] Providence [illegible] Slightly [illegible]
Effects on Air Quality*	1,6,8,9	During Construction Slightly Negative, After None	Negligible	No	During Construction Slightly Negative, After None	Negligible
Effects on Terrestrial Vegetation		Negligible	No	No	Negative	No
Effect on Local Wildlife Breeding Habitat	1,6,8,9	Negligible	No	No	Negligible	No
Rare, Endangered or Unique Species Affected	2,6,8,9	No	No	No	No	No
Scenic, Recreation or Wilderness Areas Affected*	1,6,8,9	None Other Than Those Protected Against Flooding	No	No	None Other Than Those That are Protected Against Flooding	No
Historical and/or Archeological Sites Affected*	1,[illegible]	Possible Effect on Natick Mill Village - NF	Possibility of Disturbing Floor of Apponaug Cove - NF	No	Possible Effect on Natick Mill Village - NF	Possibility [illegible] Floor of A[illegible]
Effect on Stream Erosion	1,6	During Construction Slightly Negative After - Slightly Positive	Negligible	No	During Construction Slightly Negative After - Slightly Positive	Negligible [illegible]
Mineral Resources Affected	1,6,8,9	None Other Than Materials Needed to Implement the Project	None Other Than Materials Needed to Implement the Project	Negligible	None Other Than Materials Needed to Implement the Project	None Other [illegible] Needed to [illegible]
Effect on Area Water Table	1,6,8,9	No	No	No	No	No
Effect on Transportation System	1,6,8,9	Fewer Roads Subject to Inundation - Positive During Construction - Negative	I-95 Will Remain Open Under All Flood Conditions - Positive	Negligible	Fewer Roads Subject to Inundation - Positive During Construction - Negative	I-95 Will [illegible] All Flood [illegible] Positive
Effect on Deposition in Apponaug Cove	[illegible],3,[illegible],8,9	NA	Slightly Negative	No	NA	Slightly [illegible]
3. Social Well-Being						
Flood Protection						
100 Year Flood-Complete Protection						
Residences Protected	1,6,8,9	170	No	No	268	No
Businesses Protected	1,6,8,9	19	No	No	30	No
Industrial Concerns Protected	1,6,8,9	8	No	No	17	No
Schools Protected	1,6,8,9	1	No	No	1	No
Municipal Sewage Treatment Facilities Protected	1,6,8,9	2	No	No	2	No
Other Public Buildings Protected	1,6,8,9	0	No	No	0	No
Miscellaneous		5	No	No	5	No
Percent of Flood Prone Structures Completely Protected	1,6,8,9	44	No	No	69	No
Standard Project Flood Level - Complete Protection						
Residences Protected	1,6,8,9	834	No	No	1029	No
Businesses Protected	1,6,8,9	[illegible]3	No	No	44	No
Industrial Concerns Protected	1,6,8,9	[illegible]3	No	No	23	No
Schools Protected	1,6,8,9	2	No	No	2	No
Municipal Sewage Treatment Facilities Protected	1,6,8,9	1	No	No	1	No
Other Public Buildings Protected	1,6,8,9	1	No	No	1	No
Miscellaneous	1,6,8,9	3	No	No	[illegible]	No
Percent of Flood Prone Structures Completely Protected	1,6,8,9	4[illegible]	No	No	59	No
Effect on Downstream Flooding	2,3,6,8,9	Downstream Flooding Reduced Positive	No	No	Downstream Flooding Reduced Positive	No
Relocations Required*	1,6,8,9	1 Home Purchased	No	No	7 Homes Purchased Several Utility Sheds	No
Bridge Modifications or Removal	1,6,8,9	No	No	No	2 - at Geigy Chemical Company 1 - at Elmwood Avenue	No
Roads Severed	1,6,8,9	No	No	No	1 at the Intersection of Sumner and Mill Streets	No
Socially Important Sites Affected (Churches, Cemeteries, etc.)	2,3,6,8,9	Reduced Flood Stages at 1 Church and 1 Cemetery	No	No	Reduced Flood Stages at 1 Church and 1 Cemetary	No
Effect on Public Health and Safety *	2,3,6,8,9	Highly Beneficial Due to Alleviating Flood Threat	Negligible	No	Highly Beneficial Due to Alleviating of Flood Threat	Negligible
Effect on Available Water Supply	2,4,8,9	Could Possible Allow Scituate Reservoir to Remain Full at All Times Slightly Positive	Slightly Positive	No	Could Possibly Allow Scituate Reservoir to Remain Full At All Times Slightly Positive	Slightly P[illegible]
Effect on Recreation Activities - Pawtuxet River	2,3,6,8,9	Existing Recreation Facilities Subject to Less Flooding Slightly Positive	No	No	Existing Recreation Facilities Subject to Less Flooding Slightly Positive	No
Dam Modification or Removal	1,6,7,9	New Dam at Intake Structure	No	No	New Dam at Intake Structure	No
Length of Concrete Walls for Local Protection Project (L.F.)	1,6,8,9	0	No	No	2900	No
Length of Earth Dikes for Local Protection Project (L.F.)	1,6,8,9	[illegible]			[illegible]	

TABLE 2-21
OF ACCOUNTS
A, B, & C

PLAN B NATICK DIVERSION AND WARWICK LOCAL PROTECTION PROJECT - 30' DIAMETER TUNNEL LOCATION OF IMPACTS			PLAN C NATICK DIVERSION AND WARWICK LOCAL PROTECTION PROJECT - 21' DIAMETER TUNNEL LOCATION OF IMPACTS		
Within the Watershed	Within the Rest of the SMSA	Within the Rest of the Nation	Within the Watershed	Within the Rest of the SMSA	Within the Rest of the Nation
4,029,900			3,623,500		
970,100		242,500	739,500		184,875
5,000,000		242,500	4,363,000		184,875
5,552,000			4,250,000		
0.90			1.03		
		242,500	103,000		184,874
No	No	No	No	No	No
-4.4	No	No	-4.4	No	No
+2	No	No	+2	No	No
+372	No	No	+372	No	No
+770	No	No	+770	No	No
NQ	14,500	NQ	NQ	14,500	NQ
300,000	NQ	NQ	100,000	NQ	NQ
NA	See Table 2-22	No	NA	See Table 2-22	No
3 Sewage Treatment Plants Remain Operative During Floods - Positive	Reduces Pollutional Load Providence River - Slightly Positive	Negligible	3 Sewage Treatment Plants Remain Operative During Floods - Positive	Reduces Pollutional Load to Providence River - Slightly Positive	No
During Construction Slightly Negative, After None	Negligible	No	During Construction Slightly Negative, After None	Negligible	No
Negative	No	No	Negative	No	No
Negligible	No	No	Negligible	No	No
No	No	No	No	No	No
None Other Than Those That are Protected Against Flooding	No	No	None Other Than Those That are Protected Against Flooding	No	No
Possible Effect on Natick Mill Village - NE	Possibility of Disturbing Floor of Apponaug Cove - NE	No	Possible Effect on Natick Mill Village - NE	Possibility of Disturbing Floor of Apponaug Cove - NE	No
During Construction Slightly Negative After - Slightly Positive	Negligible	No	During Construction - Slightly Negative - After Slightly Positive	Negligible	No
None Other Than Materials Needed to Implement the Project	None Other Than Materials Needed to Implement the Project	Negligible	None Other Than Materials Needed to Implement the Project	None Other Than Materials Needed to Implement the Project	Negligible
No	No	No	No	No	No
Fewer Roads Subject to Inundation - Positive During Construction - Negative	I-95 Will Remain Open Under All Flood Conditions - Positive	Negligible	Fewer Roads Subject to Inundation - Positive During Construction - Negative	I-95 Will Remain Open Under All Flood Conditions- Positive	Negligible
NA	Slightly Negative	No	NA	Slightly Negative	No
268	No	No	268	No	No
30	No	No	30	No	No
17	No	No	17	No	No
1	No	No	1	No	No
2	No	No	2	No	No
0	No	No	0	No	No
5	No	No	5	No	No
69	No	No	69	No	No
1029	No	No	806	No	No
44	No	No	30	No	No
23	No	No	16	No	No
2	No	No	0	No	No
1	No	No	0	No	No
1	No	No	0	No	No
3	No	No	2	No	No
59	No	No	46	No	No
Downstream Flooding Reduced Positive	No	No	Downstream Flooding Reduced Positive	No	No
7 Homes Purchased Several Utility Sheds	No	No	7 Homes Purchased Several Utility Sheds	No	No
2 - at Geigy Chemical Company 1 - at Elmwood Avenue	No	No	2 - At Geigy Chemical Company 1 - At Warwick Avenue 1 - At Elmwood Avenue	No	No
1 at the Intersection of Sumner and Mill Streets	No	No	1 - At the Intersection of Sumner and Mill Streets	No	No
Reduced Flood Stages at 1 Church and 1 Cemetary	No	No	Reduced Flood Stages at 1 Church and 1 Cemetary	No	No
Highly Beneficial Due to Alleviating of Flood Threat	Negligible	No	Highly Beneficial due to Alleviating Flood Threat	Negligible	No
Could Possibly Allow Scituate Reservoir to Remain Full At All Times Slightly Positive	Slightly Positive	No	Could Possibly Allow Scituate Reservoir to Remain Full at all Times - Slightly Positive	Slightly Positive	No
Existing Recreation Facilities Subject to Less Flooding Slightly Positive	No	No	Existing Recreation Facilities Subject to Less Flooding Slightly Positive	No	No
New Dam at Intake Structure	No	No	New Dam at Intake Structure	No	No
[illegible]	No	No	2900	No	No

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Schools Protected	1,6,8,9	2	No	No	2	No
Municipal Sewage Treatment Facilities Protected	1,6,8,9	1	No	No	1	No
Other Public Buildings Protected	1,6,8,9	1	No	No	1	No
Miscellaneous	1,6,8,9	1	No	No	3	No
Percent of Flood Prone Structures Completely Protected	1,6,8,9	40	No	No	59	No
Effect on Downstream Flooding	2,3,6,8,9	Downstream Flooding Reduced Positive	No	No	Downstream Flooding Reduced Positive	No
Relocations Required*	1,6,8,9	1 Home Purchased	No	No	7 Homes Purchased Several Utility Sheds	No
Bridge Modifications or Removal	1,6,8,9	No	No	No	2 - at Geigy Chemical Company 1 - at Elmwood Avenue	No
Roads Severed	1,6,8,9	No	No	No	1 at the Intersection of Sumner and Mill Streets	No
Socially Important Sites Affected (Churches, Cemetaries, etc.)	2,3,6,8,9	Reduced Flood Stages at 1 Church and 1 Cemetery	No	No	Reduced Flood Stages at 1 Church and 1 Cemetary	No
Effect on Public Health and Safety *	2,3,6,8,9	Highly Beneficial Due to Alleviating Flood Threat	Negligible	No	Highly Beneficial Due to Alleviating of Flood Threat	Negligible
Effect on Available Water Supply	2,4,8,9	Could Possible Allow Scituate Reservoir to Remain Full at All Times Slightly Positive	Slightly Positive	No	Could Possibly Allow Scituate Reservoir to Remain Full At All Times Slightly Positive	Slightly Positive
Effect on Recreation Activities - Pawtuxet River	2,3,6,8,9	Existing Recreation Facilities Subject to Less Flooding Slightly Positive	No	No	Existing Recreation Facilities Subject to Less Flooding Slightly Positive	No
Dam Modification or Removal	1,6,7,9	New Dam at Intake Structure	No	No	New Dam at Intake Structure	No
Length of Concrete Walls for Local Protection Project (L.F.)	1,6,8,9	0	No	No	2900	No
Length of Earth Dikes for Local Protection Project (L.F.)	1,6,8,9	400	No	No	8300	No
Effect on Recreation Activities - Apponaug Cove	2,3,4,8,9	No	Psychological Effect of Tunnel - Slightly Negative	No	No	Psychological Effect of Tunnel Slightly Negative
Effect on Community Cohesion *	2,3,5,8,9	Less Flood Threat - Positive	No	No	Less Flood Threat - Positive	No
Effect on Community Growth*	2,3,5,8,9	Lands Now Flood Prone Will be Dry - Positive	Slightly Positive	No	Lands Now Flood Prone are Dry - Positive	Slightly Positive
Duration of Construction Activities	1,6,7,9	4 Years	No	No	4 Years	No
4. Regional Development						
Income						
Increases in the area in long run as unemployed or underemployed labor factor inputs rejoin the labor force	1,6,7,9	Yes	Yes	No	Yes	Yes
Increases in the area from expenditure by imported construction workers	1,6,7,9	Yes	Yes	No	Yes	Yes
Employment*						
Increases employment in area during plan implementation	1,6,7,9	Yes	Yes	No	Yes	Yes
Increases employment in area in the long run	2,3,6,7,9	Yes	Yes	No	Yes	Yes
Expands the labor force in the area	1,2,6,7,9	Yes	Yes	No	Yes	Yes
Population						
Encourages long run growth in the region	2,3,6,9	NE	NE	No	NE	NE
Desirable Community Growth *						
Intensification of existing land use	2,3,6,7,9	Yes	NE	No	Yes	NE
Contribute to existing development by reducing depressing economic effects of flood damages	2,3,6,7,9	Yes	NE	No	Yes	NE
Reduce flood insurance premiums	2,3,6,9	Yes	No	No	Yes	No
Removes restriction on federally related financing for existing flood-prone properties	2,3,6,9	Yes	No	No	Yes	No
Compatible with city wide objectives for future land use	2,3,6,9	Yes	No	No	Yes	No
Increases industrial activity*	2,3,6,8,9	Yes	NE	No	Yes	NE
Taxes and Government Spending *						
Increases business activity and tax revenues*	2,3,6,9	Yes	No	No	Yes	No
Improves property values*	2,3,6,9	Yes	No	No	Yes	No
Encourages municipal expenditures to improve community facilities (new water and sewer lines, new utilities, improved or new streets)*	2,3,6,9	Yes	No	No	Yes	No

	[illegible]	[illegible]	0		[illegible]
	No	No	2	No	No
	No	No	46	No	No
	No	No	Downstream Flooding Reduced Positive	No	No
	No	No	7 Homes Purchased Several Utility Sheds	No	No
ny	No	No	2 - At Geigy Chemical Company 1 - At Warwick Avenue 1 - At Elmwood Avenue	No	No
mmer	No	No	1 - At the Intersection of Summer and Mill Streets	No	No
Church	No	No	Reduced Flood Stages at 1 Church and 1 Cemetary	No	No
t	Negligible	No	Highly Beneficial due to Alleviating Flood Threat	Negligible	No
ate t All	Slightly Positive	No	Could Possibly Allow Scituate Reservoir to Remain Full at all Times - Slightly Positive	Slightly Positive	No
ties	No	No	Existing Recreation Facilities Subject to Less Flooding Slightly Positive	No	No
s	No	No	New Dam at Intake Structure	No	No
	No	No	2900	No	No
	No	No	8600	No	No
	Psychological Effect of Tunnel Slightly Negative	No	No	Psychological Effect of Tunnel Slightly Negative	No
ve	No	No	Less Flood Threat - Positive	No	No
Dry -	Slightly Positive	No	Lands Now Flood Prone are Dry Positive	Slightly Positive	No
	No	No	4 Years	No	No
	Yes	No	Yes	Yes	No
	Yes	No	Yes	Yes	No
	Yes	No	Yes	Yes	No
	Yes	No	Yes	Yes	No
	Yes	No	Yes	Yes	No
	NE	No	NE	NE	No
	NE	No	Yes	NE	No
	NE	No	Yes	NE	No
	No	No	Yes	No	No
	No	No	Yes	No	No
	No	No	Yes	No	No
	NE	No	Yes	NE	No
	No	No	Yes	No	No
	No	No	Yes	No	No
	No	No	Yes	No	No

[illegible]	[illegible]	Roads within will be ... Open ... During Construction ...	Slightly Positive	Negligible	[illegible]	[illegible]ible
[illegible]	2,3,...,8,9	NA	No	No	[illegible]	[illegible]
... Well-Being						
... Protection						
... Complete Protection						
Residences Protected	1,6,8,9	[illegible]	No	No	[illegible]	[illegible]
... Protected	1,6,8,9	[illegible]	No	No	[illegible]	[illegible]
Industrial Concerns Protected	1,6,8,9	[illegible]	No	No	[illegible]	[illegible]
... Protected	1,6,8,9	No	No	No	[illegible]	[illegible]
Municipal Sewage Treatment Facilities Protected	1,6,8,9	No	No	[illegible]	[illegible]	[illegible]
... Public Buildings Protected	1,6,8,9	No	No	[illegible]	[illegible]	[illegible]
... Completed ... Protected	1,6,8,9	[illegible]	No	[illegible]	[illegible]	[illegible]
... Complete Protection						
Residences Protected	1,6,8,9	[illegible]	No	[illegible]	[illegible]	[illegible]
Businesses Protected	1,6,8,9	[illegible]	No	[illegible]	[illegible]	[illegible]
Industrial Concerns Protected	1,6,8,9	[illegible]	No	[illegible]	[illegible]	[illegible]
... Protected	1,6,8,9	No	No	[illegible]	[illegible]	[illegible]
Municipal Sewage Treatment Facilities Protected	1,6,8,9	No	No	[illegible]	[illegible]	[illegible]
Other Public Buildings Protected	1,6,8,9	No	No	[illegible]	[illegible]	[illegible]
Miscellaneous	1,6,8,9	No	No	[illegible]	[illegible]	[illegible]
... and Frame Structures Completed ... Protected	1,6,8,9	[illegible]	No	No	[illegible]	[illegible]
... Downstream ...	1,6,8,9	No	No	No	[illegible]	[illegible]
... Removed	1,6,8,9	... Several ...	No	No	[illegible]	[illegible]
... Removal	1,6,8,9	At ... Chemical Company; 1 At Warwick Avenue; 1 At Elmwood Avenue	No	No	[illegible]	[illegible]
Roads ...	1,6,8,9	Near the intersection of ... and Mill Streets	No	No	[illegible]	[illegible]
... Affected						
...	1,3,6,8,9	No	No	No	[illegible]	[illegible]
... Public Health ...	1,3,6,8,9	... Beneficial ... Flood Threat	No	No	[illegible]	[illegible]
...	1,6,8,9	[illegible]	No	No	[illegible]	[illegible]
...	1,3,6,8,9	No	No	No	[illegible]	[illegible]
...	1,6,8,9	No	No	No	[illegible]	[illegible]
...	1,6,8,9	None	No	No	[illegible]	[illegible]
...	1,6,8,9	None	No	No	[illegible]	[illegible]
...	1,3,6,8,9	No	No	No	[illegible]	[illegible]
...	1,3,6,8,9	... Flood Threat ...	No	No	[illegible]	[illegible]
...	1,3,6,8,9	Industries Within Will ... Expand and ...	[illegible]	[illegible]	[illegible]	[illegible]
...	1,6,8,9	7 Years	No	No	[illegible]	[illegible]

... Development

Income

12

	PLAN [illegible] [illegible] RIVER RESERVOIR LOCATION OF IMPACTS		PLAN [illegible] NO ACTION LOCATION OF IMPACTS	
Within the Watershed	Within the Rest of the SMSA	Within the Rest of the Nation	Within the Watershed	Within the Rest of the Nation
725,000				
None Allowed [illegible]				
725,[illegible]				
3,[illegible] [illegible]				
1,6[illegible]				
27[illegible]				
Negligible	No	No	No	No
No	No	No	No	No
No	No	No	No	No
Negli[illegible]	No	No	No	No
Slight[illegible]	No	No	No	No
No	No	No	NA	No
NA	No	No	NA	No
No	No	No	No	No
No	No	No	No	No
During Construction Slightly Negative, After None	Negligible	Negligible	No	No
Possibly Negative	No	No	No	No
Loss [illegible]	No	No		
Slightly Negative			No	No
No	No	No	No	No
Loss [illegible]	No	No		
Negative			No	No
Negative	No	No	No	No
Slightly [illegible]	No	No	No	No
No	No	No	No	No
Negative	No	No	No	No
Some [illegible] Relocations	Negligible	Negligible	No	No
Slightly Negative				
No	No	No	No	No
		No		
21	No	No	No	No
2	No	No	No	No
5	No	No	No	No
4	No	No	No	No
1	No	No	No	No
2	No	No	No	No
0	No	No	No	No
8	No	No	No	No
			No	No
85	No	No	No	No
2	No	No	No	No
3	No	No	No	No
3	No	No	No	No
0	No	No	No	No
0	No	No	No	No
0	No	No	No	No
5	No	No	No	No
Reduced [illegible]	No	No		
No	No	No	No	No
No	No	No	No	No
Yes	No	No	No	No
Yes	No	No	No	No
Slightly Negative	No	No	No	No
Increased [illegible] Positive	Slightly Positive	No	No	No
Negative	No	No	No	No
Yes	No	No	No	No
No	No	No	No	No
No	No	No	No	No
No	No	No	No	No
Less [illegible] Positive	No	No	No	No
No	No	No	No	No
5 Years	No	No	No	No

Protected	1,6,8,9	No	[illegible]	No		
Other Public Buildings Protected	1,6,8,9	No	No	No	0	No

	No	No	No	No
	No	No		

= Yes
= No

TABLE [illegible]
SYSTEM OF ACCOUNTS
PLANS [illegible]

Accounts	Footnotes	PLAN C — NATICK DIVERSION & WARWICK AVE LOCAL PROTECTION PROJECT [illegible] — LOCATION OF IMPACTS — Within the Watershed	Within the Rest of the SMSA	Within the Rest of the Nation	PLAN B — [illegible] WITH [illegible] & WARWICK AVE LOCAL [illegible] — LOCATION OF IMPACTS — Within the Watershed	Within the Rest of the [illegible]
[illegible] National Economic Development						
Beneficial Impacts						
Value of Increased Outputs of Goods and Services						
Flood Control Benefits		1,6[illegible],800			[illegible]	
Value of Output from Use of Unemployed or Underemployed Resources in Construction or Installation						
ARA Benefits		300,200		[illegible]	None Allowed	
Total NED Benefits		4,33[illegible],000		[illegible],000	[illegible]	
Adverse Impacts						
Total Project Costs		4,045,000			[illegible]	
B/C RATIO		[illegible]			[illegible]	
NET NED BENEFITS		2[illegible]3,302		[illegible]	[illegible]	
[illegible] Environmental Quality						
Wetlands Gained or Lost (+ Acres)	[illegible],5,9	No	No	No	Negligible	No
Natural Channel Bottom Lost (Acres)	1,6,8,9	[illegible]	No	No	[illegible]	No
Improved Channel Bottom Gained (Acres)	1,6,8,9	+2	No	No	+[illegible]	No
Floodway Gained or Lost (+ Acres)	1,6,8,9	+172	No	No	+3[illegible]	No
[illegible] Fringe Gained or Lost (+ Acres)	1,6,8,9	[illegible]	No	No	+13	No
Dredged Material to be Spoiled (cy)	1,6,7,9	NQ	No	No	No	No
Amount of Rock to be Spoiled (cy)	1,6,7,9	[illegible],000	No	No	No	No
Effect on Marine Flora & Fauna *		NA	See Table [illegible]	No	NA	No
Effect on Water Quality in Pawtuxet River *	2,3,6	Sewage Treatment Plants Remain Operable - Positive	Reduces Pollutional Load to Providence River - Positive	No	No	No
Effect on Air Quality*	1,6,8,9	During Construction - Slightly Negative After Construction - None	Negligible	No	During Construction Slightly Negative, After None	Negligible
Effect on Terrestrial Vegetation		Negative	No	No	Negative	No
Effect on Local Wildlife Breeding Habitat	1,6,8,9	Negligible	No	No	Loss of Wetlands - Slightly Negative	No
Rare, Endangered or Unique Species Affected	[illegible],6,8,9	No	No	No	No	No
Scenic, Recreation or Wilderness Areas Affected*	1,6,8,9	None Other Than Those Protected Against Flooding - Positive	No	No	Loss of Recreation Area - Slightly Negative	No
Historical and/or Archeological Sites Affected*	1,6	Possible Effect on Natick Mill Village - NE	Possibility of Disturbing Floor of Apponaug Cove - NE	No	Slightly Negative	No
Effect on Stream Erosion	1,6	During Construction - Slightly Negative After Construction - Slightly Positive	Negligible	No	Slightly Positive	No
Mineral Resources Affected	1,6,8,9	None Other Than Materials Needed to Implement the Project	None Other Than Materials Needed to Implement the Project	Negligible	No	No
Effect on Area Water Table	1,6,8,9	No	No	No	Negative	No
Effect on Transportation System	1,6,8,9	Fewer Roads Subject to Inundation - Positive, During Construction - Negative	I-95 Will Remain Open Under All Flood Conditions - Positive	Negligible	Some Roads Relocated - Slightly Negative	I-95 Will Remain Open [illegible] Flood Conditions - Po[illegible]
Effect on Deposition in Apponaug Cove	2,3,[illegible],8,9	NA	Slightly Negative	No	No	No
[illegible] Social Well-Being						
Flood Protection						
[illegible] Year Flood-Complete Protection						
Residences Protected	1,6,8,9	190	No	No	140	No
Businesses Protected	1,6,8,9	2[illegible]	No	No	18	No
Industrial Concerns Protected	1,6,8,9	16	No	No	14	No
Schools Protected	1,6,8,9	1	No	No	1	No
Municipal Sewage Treatment Facilities Protected	1,6,8,9	2	No	No	1	No
Other Public Buildings Protected	1,6,8,9	0	No	No	2	No
Miscellaneous		5	No	No	0	No
Percent of Flood Prone Structures Completely Protected	1,6,8,9	52	No	No	38	No
Standard Project Flood Level - Complete Protection						
Residences Protected	1,6,8,9	728	No	No	385	No
Businesses Protected	1,6,8,9	27	No	No	23	No
Industrial Concerns Protected	1,6,8,9	15	No	No	13	No
Schools Protected	1,6,8,9	0	No	No	0	No
Municipal Sewage Treatment Facilities Protected	1,6,8,9	0	No	No	0	No
Other Public Buildings Protected	1,6,8,9	0	No	No	0	No
Miscellaneous		2	No	No	0	No
Percent of Flood Prone Structures Completely Protected	1,6,8,9	42	No	No	23	No
Effect on Downstream Flooding	2,3,6,8,9	Downstream Flooding Reduced Positive	No	No	Flooding Reduced - Positive	No
Relocations Required *	1,6,8,9	1 House 1 Shed	No	No	No	No
Bridge Modifications or Removal	1,6,8,9	2 at Geigy Chemical Company 1 at Warwick Avenue	No	No	2 at Geigy Chemical Company 1 at Warwick Avenue	No
Roads Severed	1,6,8,9	No	No	No	Yes	No
Socially Important Sites Affected (Churches, Cemetaries, etc.) *	2,3,6,8,9	Reduced Flood Stages at 1 Church and 1 Cemetary	No	No	Yes	No
Effect on Public Health and Safety *	2,3,6,8,9	Highly Beneficial Due to Alleviating of Flood Threat	Negligible	No	Beneficial Due to Alleviating of Flood Threat	No
Effect on Available Water Supply	2,4,8,9	Could Possibly Allow Scituate Reservoir to Remail Full at All Times Slightly Positive	Slightly Positive	No	Increased Water Supply - Positive	Slightly Positive
Effect on Recreation Activities - Pawtuxet River	2,3,6,8,9	Existing Recreation Facilities Subject to Less Flooding Slightly Positive	No	No	Negative	No
Dam Modification or Removal	1,6,7,9	New Dam at Intake Structure	No	No	Yes	No
Length of Concrete Walls for Local Protection Project (L.F.)	1,6,8,9	2400	No	No	2900	No
Length of Earth Dikes for Local Protection Project (L.F.)	1,6,8,9	3400	No	No	8300	No
Effect on Recreation Activities - Apponaug Cove	2,3,4,8,9	No	Psychological Effect of Tunnel - Slightly Negative	No	No	No
Effect on Community Cohesion*	2,3,5,8,9	Less Flood Threat - Positive	No	No	Less Flood Threat - Positive	No
Effect on Community Growth*	2,3,5,8,9	Lands Currently Flood Prone are Dry - Positive	Slightly Positive	No	No	No
Duration of Construction Activities	1,6,7,9	4 Years	No	No	5 Years Entire Project	No

4. **Regional Development**

TABLE 2-21 (cont)
SYSTEM OF ACCOUNTS
PLANS G, H, & I

PLAN H — BIG RIVER RESERVOIR WITH ELMWOOD & WARWICK AVE LOCAL PROTECTION PROJECTS — LOCATION OF IMPACTS			PLAN I — BIG RIVER MULTI-USE RESERVOIR* WITH WARWICK AVE LOCAL PROTECTION PROJECT AND NORWOOD LAND BANK — LOCATION OF IMPACTS		
Within the Watershed	Within the Rest of the SMSA	Within the Rest of the Nation	Within the Watershed	Within the Rest of the SMSA	Within the Rest of the Nation
2,001,000			1,801,500		
None Allowed			None Allowed (1980)		
2,001,000			1,801,500		
1,770,000			1,429,300		
1.13			1.26		
231,000			372,700		
Negligible	No	No	No	No	No
-4.4	No	No	-4.4	No	No
+2	No	No	+2	No	No
-37	No	No	-20	No	No
+130	No	No	+130	No	No
No	No	No	No	No	No
No	No	No	NA	NA	No
NA	NQ	No	No	No	No
No	No	No	Less Chance of Septic Tank Overflow Overflow - Slightly Positive	Negligible	No
During Construction Slightly Negative, After None	Negligible	Negligible	During Construction- Slightly Negative; After Construction None	No	No
Negative	No	No	Negative	No	No
Loss of Wetlands - Slightly Negative	No	No	Negligible	No	No
No	No	No	No	No	No
Loss of Recreation Area - Slightly Negative	No	No	No	No	No
Slightly Negative	No	No	No	No	No
Slightly Positive	No	No	During Construction - Slightly Negative After Construction None	No	No
No	No	No	None Other Than Materials Needed to Implement the Project	No	No
Negative	No	No	No	No	No
Some Roads Relocated - Slightly Negative	1-95 Will Remain Open During Flood Conditions - Positive	Negligible	Not Known at this Time	Not Known at this Time	No
No	No	No	No	No	No
140	No	No	30 exclusive of acquisition	No	No
18	No	No	15	No	No
14	No	No	13	No	No
1	No	No	1	No	No
1	No	No	1	No	No
2	No	No	2	No	No
0	No	No	0	No	No
38	No	No	13	No	No
385	No	No	275 exclusive of acquisition	No	No
23	No	No	20	No	No
13	No	No	12	No	No
0	No	No	0	No	No
0	No	No	0	No	No
0	No	No	0	No	No
0	No	No	0	No	No
23	No	No	16	No	No
Flooding Reduced - Positive	No	No	Flooding Reduced - Positive	no	No
No	No	No	1 Shed 40 to 54 Houses	No	No
2 at Geigy Chemical Company 1 at Warwick Avenue	No	No	2 at Geigy Chemical Co. 1 at Warwick Ave.	No	No
Yes	No	No	Yes	No	No
Yes	No	No	Yes	No	No
Beneficial Due to Alleviating of Flood Threat	No	No	Beneficial Due to Alleviating Flood Threat	No	No
Increased Water Supply - Positive	Slightly Positive	No	Increased Water Supply - Positive	Positive	No
Negative	No	No	Negative	No	No
Yes	No	No	New Dam at Big River Structure	No	No
2900	No	No	2400	No	No
8300	No	No	3400	No	No
No	No	No	No	No	No
Less Flood Threat - Positive	No	No	Some Homes Relocated - Negative	No	No
No	No	No		No	No

[illegible]	[illegible]	[illegible] Reservoir to [illegible] Full at All Times Slightly Positive	[illegible]	No	[illegible] Water Supply - Positive	Slightly Positive
Effect on Recreation Activities - Pawtuxet River	2,3,6,8,9	Existing Recreation Facilities Subject to Less Flooding Slightly Positive	No	No	Negative	No
Dam Modification or Removal	1,6,7,9	New Dam at Intake Structure	No	No	Yes	No
Length of Concrete Walls for Local Protection Project (L.P.)	1,6,8,9	2400	No	No	2900	No
Length of Earth Dikes for Local Protection Project (L.P.)	1,6,8,9	3400	No	No	8300	No
Effect on Recreation Activities - Apponaug Cove	2,3,4,8,9	No	Psychological Effect of *Tunnel - Slightly Negative*	No	No	No
Effect on Community Cohesion*	2,3,5,8,9	Less Flood Threat - Positive	No	No	Less Flood Threat - Positive	No
Effect on Community Growth*	2,3,5,8,9	Lands Currently Flood Prone are Dry - Positive	Slightly Positive	No	No	No
Duration of Construction Activities	1,6,7,9	4 Years	No	No	5 Years Entire Project	No
Regional Development						
Income						
Increases in the area in long run as unemployed or underemployed labor factor inputs rejoin the labor force	1,6,7,9	Yes	Yes	No	Yes	Yes
Increases in the area from expenditure by imported construction workers	1,6,7,9	Yes	Yes	No	Yes	Yes
Employment*						
Increases employment in area during plan implementation	1,6,7,9	Yes	Yes	No	Yes	Yes
Increases employment in area in the long run	2,3,6,7,9	Yes	Yes	No	Yes	Yes
Expands the labor force in the area	1,2,6,7,9	Yes	Yes	No	Yes	Yes
Population						
Encourages long run growth in the region	2,3,6,9	NE	NE	No	NE	NE
Desirable Community Growth*						
Intensification of existing land use	2,3,6,7,9	Yes	NE	No	Yes	NE
Contribute to existing development by reducing depressing economic effects of flood damages	2,3,6,7,9	Yes	NE	No	Yes	NE
Reduce flood insurance premiums	2,3,6,9	Yes	No	No	Yes	Negligible
Removes restriction on federally related financing for existing flood-prone properties	2,3,6,9	Yes	No	No	Yes	No
Compatible with city wide objectives for future land use	2,3,6,9	Yes	No	No	Yes	Yes
Increases industrial activity*	2,3,6,8,9	Yes	NE	No	Yes	Yes
Taxes and Government Spending*						
Increases business activity and tax revenues*	2,3,6,9	Yes	No	No	Possibly Yes	No
Improves property values*	2,3,6,9	Yes	No	No	Yes	No
Encourages municipal expenditures to improve community facilities (new water and sewer lines, new utilities, improved or new streets)*	2,3,6,9	Yes	No	No	Yes	No

y -	Highly Positive	No	Increased Water Supply - Positive	Positive	No No
	No	No	Negative	No	No
	No	No	New Dam at Big River Structure	No	No
	No	No	2400	No	No
	No	No	3400	No	No
	No	No	No	No	No
- Positive	No	No	Some Homes Relocated - Negative	No	No
	No	No		No	No
Project	No	No	5 Years Entire Project	No	No
	Yes	No	Yes	Yes	No
	Yes	No	Yes	Yes	No
	Yes	No	Yes	Yes	No
	Yes	No	Yes	Yes	No
	Yes	No	Yes	Yes	No
	NE	No	NE	NE	No
	NE	No	Yes	NE	No
	NE	No	Yes	NE	No
	Negligible	No	Yes	Negligible	No
	No	No	Yes	No	No
	Yes	Yes	No	Yes	No
	Yes	Yes	No	Yes	No
	No	No	No	No	No
	No	No	No	No	No
	No	No	No	No	No

PLAN J

NON-STRUCTURAL MEASURES

LOCATION OF IMPACTS

ACCOUNTS	Footnotes	Within the Watershed	Within the Rest of the SMSA	Within the Rest of the Nation
1. National Economic Development				
Beneficial Impacts				
Value of Increased Outputs of Goods and Services				
Flood Control Benefits		3,120,000		
Value of Output from use of Unemployed, or Underemployed Resources in Construction or Installation				
ARA Benefits		NA		
Total NED Benefits		3,120,000		
Adverse Impacts				
Total Project Costs		26,143,000		
B/C RATIO		0.12		
NET NED BENEFITS				
2. Environmental Quality				
Wetlands Gained or Lost (+ Acre)	1,6,8,9	No	No	No
Natural Channel Bottom Lost (Acres)	1,6,8,9	No	No	No
Improved Channel Bottom Gained (Acres)	1,6,8,9	No	No	No
Floodway Gained or Lost (+ Acres)	1,6,8,9	Negligible	No	No
Flood Fringe Gained or Lost (+ Acres)	1,6,8,9	Negligible	No	No
Dredged Material to be Spoiled (cy)	1,6,7,9	No	No	No
Amount of Rock to be Spoiled (cy)	1,6,7,9	No	No	No
Effect on Marine Flora & Fauna		Negligible	No	No
Effect on Water Quality to Pawtuxet River*	2,3,6	Negligible	No	No
Effects on Air Quality*	1,6,8,9	No	No	No
Effects on Terrestrial Vegetation		Positive	No	No
Effect on Local Wildlife Breeding Habitat	1,6,8,9	Positive due to Relocation out of Flood Fringe	No	No
Rare, Endangered or Unique Species Affected	2,6,8,9	No	No	No
Scenic, Recreation or Wilderness Areas Affected*	1,6,8,9	No	No	No
Historical and/or Archeological Sites Affected*	1,4	No	No	No
Effect on Stream Erosion	1,6	No	No	No
Mineral Resources Affected	1,6,8,9	No	No	No
Effect on Area Water Table	1,6,8,9	No	No	No
Effect on Transportation System	1,6,8,9	No	No	No
Effect on Deposition in Apponaug Cove	2,3,4,8,9	No	No	No
3. Social Well-Being				
Flood Protection				
100-Year Flood-Complete Protection				
Residences Protected	1,6,8,9	393	No	No
Businesses Protected	1,6,8,9	42	No	No
Industrial Concerns Protected	1,6,8,9	23	No	No
Schools Protected	1,6,8,9	2	No	No
Municipal Sewage Treatment Facilities Protected	1,6,8,9	3	No	No
Other Public Buildings Protected	1,6,8,9	2	No	No
Miscellaneous		6	No	No
Percent of Flood Prone Structures Completely Protected	1,6,8,9	100	No	No
Standard Project Flood Level - Complete Protection				
Residences Protected	1,6,8,9	1076	No	No
Businesses Protected	1,6,8,9	82	No	No
Industrial Concerns Protected	1,6,8,9	40	No	No
Schools Protected	1,6,8,9	5	No	No
Municipal Sewage Treatment Facilities Protected	1,6,8,9	3	No	No
Other Public Buildings Protected	1,6,8,9	8	No	No
Miscellaneous	1,6,8,9	12	No	No
Percent of Flood Prone Structures Completely Protected	1,6,8,9	48	No	No
Effect on Downstream Flooding	2,3,6,8,9	No	No	No
Relocations Required*	1,6,8,9	616	No	No
Bridge Modifications or Removal	1,6,8,9	No	No	No
Roads Severed	1,6,8,9	No	No	No
Socially Important Sites Affected (Churches, Cemetaries, etc.)	2,3,6,8,9	No	No	No
Effect on Public Health and Safety*	2,3,6,8,9	Positive-Less Flood Threat	Negligible	No
Effect on Available Water Supply	2,4,8,9	No	No	No
Effect on Recreation Activities Pawtuxet River	2,3,6,8,9	Positive-Provides Additional Open Space Along River	No	No
Dam Modification or Removal	1,6,7,9	No	No	No
Length of Concrete Walls for Local Protection Project (L.P.)	1,6,8,9	NA	NA	NA
Length of Earth Dikes for Local Protection Project (L.P.)	1,6,8,9	NA	NA	NA
Effect on Recreation Activities - Apponaug Cove	2,3,4,8,9	No	No	No
Effect on Community Cohesion*	2,3,5,8,9	Relocated Families may leave area	No	No
Effect on Community Growth*	2,3,5,8,9	Relocated Families may leave area	Slight Increase Possible	Negligible
Duration of Construction Activities	1,6,7,9	5-10	No	No

4. Regional Development

Effect on Recreation Activities Pawtuxet River	**2,3,6,8,9**	***Positive-Provides Additional*** Open Space Along River	**No**	**No**
Dam Modification or Removal	1,6,7,9	No	No	No
Length of Concrete Walls for Local Protection Project (L.F.)	1,6,8,9	NA	NA	NA
Length of Earth Dikes for Local Protection Project (L.F.)	1,6,8,9	NA	NA	NA
Effect on Recreation Activities - Apponaug Cove	2,3,4,8,9	No	No	No
Effect on Community Cohesion*	2,3,5,8,9	Relocated Families may leave area	No	No
Effect on Community Growth*	2,3,5,8,9	Relocated Families may leave area	Slight Increase Possible	Negligible
Duration of Construction Activities	1,6,7,9	5-10	No	No
4. Regional Development				
Income				
Increases in the area in long run as unemployed or underemployed labor factor inputs rejoin the labor force	1,6,7,9	Negligible	Negligible	No
Increases in the area from expenditure by imported construction workers	1,6,7,9	Negligible	Negligible	No
Employment*				
Increases employment in area during plan implementation	1,6,7,9	Negligible	Negligible	No
Increases employment in area in the long run	2,3,6,7,9	No	No	No
Expands the labor force in the area	1,2,6,7,9	No	No	No
Population				
Encourages long run growth in the region	2,3,6,9	No	No	No
Desirable in Community Growth*				
Intensification of existing land use	2,3,6,7,9	No	No	No
Contribute to existing development by reducing depressing economic effects of flood damages	2,3,6,7,9	Yes	No	No
Reduce flood insurance premiums	2,3,6,9	Yes	No	No
Removes restriction on federally related financing for existing floodprone properties	2,3,6,9	Yes	No	No
Compatible with city wide objectives for future land use	2,3,6,9	Yes	No	No
Increases industrial activity*	2,3,6,8,9	Yes	Yes	No
Taxes and Government Spending*				
Increases business activity and tax revenues*	2,3,6,9	Yes	Yes	No
Improves property values*	2,3,6,9	Yes	No	No
Encourages municipal expenditures to improve community facilities (new water and sewer lines, new utilities, improved or new streets)*	2,3,6,9	No	No	No

TABLE 2-22

EFFECTS ON MARINE FLORA & FAUNA *
SUPPLEMENT TO SYSTEM OF ACCOUNTS
APPLIES TO ALTERNATIVES C-1 AND C-2 ONLY
AFFECTED AREA IS LIMITED TO APPONAUG COVE - GREENWICH BAY AREA

Species	Footnotes	Yearly Diversion Rate 21' & 30' Dia. Tunnel	15 Year Diversion Rate 21' & 30' Dia. Tunnel	100 Year Diversion Rate 21' & 30' Dia. Tunnel	14,500 CFS Diversion Rate 30' Dia. Tunnel Only
Winter Flounder					
Early Life Stages - Eggs & Larvae	2, 3, 4, 9	Negligible	Destruction of Year Class in Apponaug Cove and Portions of Greenwich Bay	Destruction of Year Class in Apponaug Cove and Portions of Greenwich Bay	Destruction of Year Class in Apponaug Cove and Large Portion of Greenwich Bay
Adult Stages	2, 3, 4, 9	Negligible	Negligible to Slight	Some Mortality	Some Mortality
Alewife					
Adult	2, 3, 4, 9	Negligible	May Affect Homing Instinct and Result in Loss of Major Portion of Spawning	May Affect Homing Instinct and Result in Loss of Major Portion of Spawning	May Affect Homing Instinct and Result in Loss of Major Portion of Spawning
Quahog					
Early Life Stages-Eggs & Larvae	2, 3, 4, 9	Negligible	Destruction of Year Class in Apponaug Cove and Portions of Greenwich Bay	Destruction of Year Class in Apponaug Cove and Portions of Greenwich Bay	Destruction of Year Class in Apponaug Cove and Large Portion of Greenwich Bay
Adult Stages	2, 3, 4, 9	Negligible	Slight	Minor Mortality	Some Mortality
Soft Shell Clam					
Early Life Stages - Eggs & Larvae	2, 3, 4, 9	Negligible	Destruction of Year Class in Apponaug Cove and Portions of Greenwich Bay	Destruction of Year Class In Apponaug Cove and Portions of Greenwich Bay	Destruction of Year Class in Apponaug Cove and Most of Greenwich Bay
Adult Stages	2, 3, 4, 9	Negligible	Slight	Loss of First Year Class & Possible Adults in Apponaug Cove and Small Portions of Greenwich Bay	Loss of First Year Class & Possible Adults in Apponaug Cove and Portions of Greenwich Bay
Gemma Gemma	2, 3, 6, 9	Negligible	Benthic Community Structure in Apponaug Cove Affected	Loss in Apponaug Cove	Loss in Apponaug Cove
Razor Clam					
Early Life Stages - Eggs & Larvae	2, 3, 6, 9	Negligible	Destruction of Year Class in Apponaug Cove and Portions of Greenwich Bay	Destruction of Year Class in Apponaug Cove and Large Portions of Greenwich Bay	Destruction of Year Class in Apponaug Cove and Greenwich Bay
Adult Stages	2, 3, 4, 9	Negligible	Negligible to Slight	Slight	Some Mortality
Other Invertebrates					
Mostly Polychaetes	2, 3, 6, 9	Negligible	Possible Change in Benthic Community Structure in Apponaug Cove	Possible Change in Benthic Community Structure in Apponaug Cove and Portions of Greenwich Bay	Possible Change in Benthic Community Structure Throughout Apponaug Cove and All of Greenwich Bay

The timing of a flood event is important to impact predictions. Some marine animals spawn in different seasons and the commencement of spawning may depend on environmental ques, such as, temperature or duration of daylight. The impact to each animal listed has been considered, as though a flood event occurred shortly after its respective spawning period. All animals listed will not be similarly affected by a particular flood event because of their different spawning periods and stage of development.

APPENDIX 3

PUBLIC VIEWS & RESPONSES

TABLE OF CONTENTS

DESCRIPTION OF PUBLIC INVOLVEMENT PROGRAM

In keeping with the policy of the Chief of Engineers to conduct the Civil Works program in an atmosphere of public understanding, trust, and mutual cooperation, all interested individuals and agencies were informed and afforded an opportunity to be fully heard and their views considered in arriving at conclusions, decisions, and recommendations in the formulation of civil works proposals, plans, and projects and on the proposed uses of navigable waters. Formally organized and announced public meetings provide one important means of accomplishing this objective. Other desirable public participation and information measures such as workshops and close coordination between towns and individuals also contributed to this objective.

Formality is intended only in respect to organization and announcement. The atmosphere of the meetings were informal to the extent practicable, in keeping with the concept of public involvement and the need to encourage and develop more meaningful, two-way communication.

The primary purpose of the public meetings was to help to insure that solutions to flooding problems satisfy the needs and preferences of the people to the maximum degree possible within the bound of local, State, and Federal interests, responsibilities, and authorities. More specifically, the purposes of the public meetings were to inform the public about studies and proposals related to flooding and to give all interested persons an opportunity to fully and publicly express their views concerning such studies and proposals; to obtain and exchange information which will assist all those involved in arriving at sound conclusions and recommendations; and to contribute to interagency coordination.

An initial meeting was held early in the course of the study, in May 1969, to advise the nature and scope of the study, to open lines of communication, to listen to the needs and views of the public, and to identify interested individuals and agencies.

A formulation stage meeting was held during the course of the study, in May 1975; when all alternative solutions were reasonably known, generally after the completion of preliminary studies but before a plan had been tentatively selected. A meeting at this stage is critical, and its scheduling and conduct is given careful attention. A major purpose of this meeting is to present the results of preliminary studies, including the advantages and disadvantages of the various alternatives to the extent that such information has been developed, and to further develop public views and desires, particularly as they relate to the various alternatives.

If the preliminary studies reveal that further studies are unwarranted, a public meeting at this stage is held only at the discretion of the reporting officers, giving appropriate consideration to public participation concepts, including unusual circumstances.

A late stage meeting was held in 1976 after detailed studies but before report completion. Findings of the detailed studies, including the rationale for any proposed solution, and the tentative recommendations of the reporting officer were presented. In the event that, due to the nature of the study, the formulation stage meeting was, in effect, also a late stage meeting and the proposed plan was a foregone conclusion at that meeting, a late stage meeting may be dispensed with, if approved by the Division Engineer. However, it must be apparent that no residual public meeting requirement is being imposed on the Board of Engineers for Rivers and Harbors. In all cases where no structural improvements or similar investments by the Corps of Engineers are to be recommended, a late stage public meeting will be held only at the discretion of the reporting officers, giving appropriate consideration to public participation concepts, including unusual circumstances.

An additional late stage meeting may be held for those studies where there have been no recent public meetings and there are indications that public acceptance may have changed materially or that further public views should be sought. Similarly, an additional late stage meeting may be held in those cases where there have been substantive changes in the tentative plan previously presented. Such was the case in this study resulting in a public meeting in May 1977.

Following are summaries of the public meetings held in 1969, 1975, 1976 and 1977 in addition to correspondence received regarding each.

SUMMARY OF MAY 1969 PUBLIC MEETINGS

To afford individual citizens, municipal and State officials, and other Federal agencies an opportunity to present their views and desires concerning the need and extent of improvements on flood reduction measures and other interrelated water-oriented resources, in the Pawtuxet Basin, four public hearings, 9, 12, 15 and 22 May 1969, were held at the initiation of the study. Though these four public hearings were intended to cover the entire Pawcatuck River and Narragansett Bay Drainage Basin (PNB) study area, as mandated by seven Congressional Resolutions, two of these hearings were held in Providence and Kingston, Rhode Island - two areas contiguous to the Pawtuxet River Basin.

All interested parties were invited to be present or represented at these hearings, including representatives of Federal, State, county and municipal agencies, and those commercial, industrial, civic, highway, railroad, water transportation, flood control and other interests and property owners concerned. They were afforded full opportunity of expressing their views concerning the character and extent of the improvements desired and the need and advisability of their execution. Sponsors of improvement measures were urged to present pertinent factual material bearing upon the general plans of improvement desired and to give detailed supporting data on the economic justification of the undertaking. Opposing interests were also urged to state the reasons for their position.

Oral statements were heard and for accuracy of the record, all important facts and arguments were submitted in writing, some handed to the hearing officer and others mailed to his office.

Most of the attendees supported and concurred in this study. Excerpts from the record which reflect their general attitude follow

The General Manager of the Rhode Island Water Resources Board brought attention to the State water supply plans which, through development of new surface reservoirs and groundwater supplies, would provide the State with an adequate supply for all purposes up the year 2020. These plans were presented in order that proper consideration would be given in light of the flood control studies.

The Warwick City Planner, who represented the Mayor, spoke about the damage created by the flood of March 1968 and the city's concern and interest in the investigation. His realm of concern centered on the intensification of land utilization causing faster runoff of surface waters in the rivers, thereby giving greater impetus to future flooding.

The Vice Chairman, Pawtuxet River Authority, formerly the Pawtuxet River Board, affirmed the "Authority" continuing purposes to be for the [illegible] of health," for the improvement of sanitation, for the abatement of nuisances, for the elimination of [illegible], for stream regulation and flood control, for reforestation, housing and recreation facilities and for such other improvements as may be found reasonably necessary and proper for the health, welfare and safety of the inhabitants of the watershed of the Pawtuxet River."

The planning developments and problems within the watershed were also presented. The most prominent developments envisioned included: construction of a large water supply impoundment on the South Branch, completion of an extensive highway construction program together with shopping centers and expansion of treatment facilities. Some of the problems to be overcome would include: the intrusion into the river of poorly treated solid wastes and erosion sediments forming benthal deposits and floating debris, the deteriorated environment which precludes canoeing and other recreational use, the reckless filling of wetlands and swamps, the fast maturing process found in many of the lakes and ponds, and flooding.

A representative of the Appalachian Mountain Club (AMC), Narragansett Chapter, urged that restraint, wherever possible, be used when study considerations include alteration or modification of natural streams and that all ecological factors be weighed. The organization supported abatement of all pollution and hoped that watershed areas developed for water supplies be not restricted to public recreation.

Subsequent to and to supplement information received at these public meetings, and to fully evaluate and update the inventory of the flood problem locations and other water resources needs, letters requesting such information were mailed to responsible local officials. Concurrently, numerous informal meetings with State agencies and the Pawtuxet River Authority, and personal contacts with Federal agencies and individual citizens were initiated.

At first, there was a lack of interest resulting mostly from an unawareness of the serious flood problems to which the Pawtuxet River watershed could be subjected. As the study progressed and the potential flood problems surfaced, meetings became more fruitful with indications of general support and genuine willingness to participate in the investigation of the study.

Since initiation of this basic study, additional requests for Federal assistance in solving specific flood problems have been requested. Some of the requests have been considered under other existing authorities available to the Corps of Engineers, such as Section 205 of the Flood Control Act of 1948, as amended. Other requests

received and processed came under the purview of the clearing and snagging authority as covered in Section 208 of the Flood Control Act of 1954, as amended.

Cognizant of the flood hazard from continuous encroachment on the flood plains, the city of Cranston requested flood plain information studies on the Pawtuxet River and three tributary streams, namely, Pocasset River, Meshanticut and Furnace Hill Brooks. The only study completed to date has been the Pocasset River, accomplished by the Soil Conservation Service, U.S. Department of Agriculture. Other streams would be coordinated with the resultant plan of this basin and with other Federal agencies where applicable and would be due for completion in the near future. All communities in the basin have applied for flood insurance assistance under the National Flood Insurance Program, and are operating under either the regular or emergency programs.

Other requests for improvement desired included channel modification involving various methods of restoration work such as:

a. Possible elimination of abrupt turns and oxbows.

b. Widening, deepening and channel realignment of certain stretches of river.

c. Improvement of waterway areas at bridges, culverts and other constriction points.

d. Selective planting and/or revetment works for alleviating erosion problems.

e. Removal of shoals, sandbars, and piles impeding minor flood flows.

f. Removal of vegetation, overhanging trees, shrubs, and accumulated silt and debris at critical points.

Numerous other requests were made involving the removal or structural stabilization of old dams as well as modification of existing lakes, ponds and reservoirs for providing an added measure of flood protection.

SUMMARY OF MAY 1975 PUBLIC MEETING

On 5 May and 8 May 1975, public meetings were held [illegible] Cranston, Rhode Island to hear comments of the alternative solutions concerning flooding and related problems of the lower reaches of the Pawtuxet River and tributary streams. Notice of the meeting went to some 700 individuals and organizations, principally in Rhode Island with about 120 in attendance between the two meetings. The meetings began with an overview of the NED study followed by a presentation explaining the technical aspects of the alternative plans proposed for the Pawtuxet River Basin. Explained were various approaches, both structural and non-structural, which were investigated to alleviate the flooding problems. The most effective structural measures proposed at that time were the so called plans "A", "A-1", "B", "B-1", "C", "C-1", and "D". Alternates "A" and "A-1" involved various systems of walls, dikes, and channel modifications. Plans "B" and "B-1" proposed different alignments of the so-called Pontiac Diversion and plans "C" and "C-1" which involved the Natick Diversion in conjunction with additional protection works. Alternate "D" was the Warwick Local Protection Project. Major emphasis, at this meeting, was placed on the Natick Diversion as it would have a substantial influence on reducing flood loss in the lower portions of the river.

Input by the people at these meetings was favorable. Comments generally were in support of the project and that the Corps of Engineers continue its study of the Pawtuxet watershed.

A resolution was read by the West Warwick Town Planner, giving the project support by the Town Council pending the results of the environmental impact statement. Senator Joe Walsh read a statement lending support of the State of Rhode Island General Assembly. Representative Ray McDonald presented a resolution identical to that of the Senates from the House of Representatives. Councilman Gerald Gibbons voiced his support for the continuing study of the diversion plan.

The Mayor of the city of Warwick, also supported the continuance of the diversion project through Mr. William E. George, City Planner for Warwick. He also stated that the formal city position will be made within 60 days of receipt of the environmental impact statement and other economic data. Also several of the residents of the affected areas also gave comments in support of the proposed project.

Questions which were asked by attendees of the meeting centered mainly on the affects of the sub-surface tunnel on the structures above, potential impacts on Apponaug Cove, affects on specific homes in the flooded area and why certain areas were omitted from receiving flood protection.

One resident of Warwick asked questions expressing concern in several areas. First he wanted to know the affects of turbulence caused by the outfall of the tunnel in the Apponaug Cove area with respect to his home in that area and erosion. Also he wanted to know how the diversion of flood water would affect the flooding problems in the cove area. A third area of consideration centered itself on the amount of silt that would be deposited in the cove and lastly the environmental impacts imposed on the Apponaug Cove.

In response to turbulence the NED staff pointed out that the higher velocities caused by the outfall would be confined within the structured cell of the tunnel and would be dissipated greatly as it enters the cove. As far as silting and deposition is concerned, the Corps is responsible for maintaining all Federal channels that they dredge so it would behoove them to prevent causing silting. It is the individual's responsibility to prevent dumping into the river, causing pollutional as well as silting problems. When something gets thrown in the river it acts as a little check dam with a resultant buildup of silt. The NED staff could not give a definite answer regarding the potential environmental impacts since the impact analysis had not as yet been completed. It was noted that they want to determine what the hydrologic condition in the cove would be, in particular the stress put on the biota as a result of the mixing of salt and fresh water. A question was raised concerning the modification or removal of Broad Street Dam in order to alleviate the flooding in a driveway. The NED staff stated that removal would have no effect since the water comes up above the dam as a result of the tides anyway.

Response was made to questions presented in a letter from the Department of Planning and Urban Planning. The first question was could we (the Corps) regulate Scituate Reservoir, Flat River Reservoir and the proposed Big River Reservoir in lieu of much of the structural features that we are considering. The response was that it has been considered and included in the analysis. The modifications necessary to provide flood control at these sites would result only in 70% of the flood control provided by the Natick Diversion. Also, in the case of Flat River Reservoir, additional water supply storage would be needed.

Another question posed was to what extent will the proposed diking intensify downstream flooding. It was stated that some of the storage along the floodplain would be lost due to diking but that would be outweighed by the amount of reduction the diversions would provide. The next question dealt with the extent to which existing small dams could be used as flood regulators. The staff responded that small dams can't be used because of their insufficient storage capacity. Also posed was a question about the possibility of channel

modification as a means of reducing flood stages. The answer given was that it would not be practical due to the hydraulic nature of the river and oxbows in general. The next question was in regards to the disposal of rock excavated from the tunnel area. The NED staff stated that some of the rock would be used at the Norwood Local Protection Project and the remainder either sold or disposed of in some other manner.

A resident of Vancouver Avenue was concerned about an easement and clear title to his home if the tunnel ran directly beneath the house. The NED staff responded by stating that the Government would take an easement and added that it shouldn't affect the potential sale of his property while mineral rights and other details would be covered in the agreements signed by the affected people.

One resident expressed the only anti-tunnel concerns at these meetings. They stated that they would not live above the tunnel and felt that it was unfair that they be subject to this while at the same time their garage was subject to flooding. Also, why couldn't the tunnel be routed into Greenwich Bay. The NED staff stated that diverting into the Bay had been studied and it was determined to be infeasible. While no plan can protect everyone, Corps representatives would be down to talk and try to make suggestions to cure their flooding problems.

A resident of Sumner Avenue raised the question as to how the homes along the river would be affected by the dike. The NED staff explained that the present alignment of the dike would affect four or five homes. These homes would be moved back, remaining in the same neighborhood. The extent of the move had not yet been determined.

A resident of West Warwick was concerned about flooding problems in Baker Street Brook. They made it a matter of record that the people abutting the brook would like to be part of the project if at all possible.

Residents of Warwick questioned the affect that drilling or blasting would have on the homes at the surface. The NED staff stated that at the present time the conventional measures of drilling and blasting were being considered although if the bedrock conditions are favorable a mole will be used. The mole is like a large hand drill that chews away at the rock. The staff didn't know exactly what the blasting affects would be although subsurface explorations were being made. Successful blasting has been done at other Corps projects and the specifications included provisions so that an excessively large charge is not used.

CORRESPONDENCE FROM 1975 PUBLIC MEETING

75 / 104

State of Rhode Island, &c.

IN GENERAL ASSEMBLY

JANUARY SESSION, A. D. 1975

SENATE RESOLUTION

RESPECTFULLY REQUESTING THE UNITED STATES ARMY CORPS OF ENGINEERS TO CONTINUE THE WATER RESOURCE STUDY OF THE PAWTUXET RIVER BASIN ESPECIALLY THE WARWICK AND NORWOOD LOCAL PROTECTION PROJECTS.

WHEREAS, Following the heavy damages suffered during the storms of March 1968 and February and April 1970, a study was undertaken to improve flood control, navigation, water supply, water quality control and allied water use of the Pawtuxet River basin; and

WHEREAS, A comprehensive approach by Federal, state, local and private agencies to flood control management provides optimum development of water resources; and

WHEREAS, The Pawtuxet River Basin which is subject to both river and tidal floods has experienced disasterous floods in 1936, 1938, 1968 and twice in 1970; and

WHEREAS, Since the 1968 flood the entire basin has undergone significant land use changes; and

WHEREAS, The Warwick Local Protection Project will provide dikes, walls, thus, affording protection to over two hundred homes, businesses and industrial establishments; and

WHEREAS, The Norwood Project would provide a dike to afford a substantial degree of flood protection for the residents of Elmwood Avenue in Warwick; now, therefore, be it

RESOLVED, That the U.S. Army Corps of Engineers is hereby commended for their excellent work and is respectfully requested to continue the water resource study of the Pawtuxet River Basin, especially the Warwick and Norwood Local Protection Projects; and be it further

RESOLVED, That the secretary of state be and he hereby is authorized and directed to transmit a duly certified copy of this resolution to the United States Army Corps of Engineers.

State of Rhode Island and Providence Plantations

Department of State

Office of the Secretary of State

I, ROBERT F. BURNS *Secretary of State of the State of Rhode Island and Providence Plantations,*

hereby Certify *that the aforegoing is a true*

copy of Senate Resolution (75-S 1104) entitled SENATE RESOLUTION RESPECTFULLY REQUESTING THE UNITED STATES ARMY CORPS OF ENGINEERS TO CONTINUE THE WATER RESOURCE STUDY OF THE PAWTUXET RIVER BASIN ESPECIALLY THE WARWICK AND NORWOOD LOCAL PROTECTION PROJECTS; the same being

taken from the records in this office and compared with the original Senate Resolution (75-S 1104) passed in the Senate at the January Session of the General Assembly, A. D. 197_ on the sixth day of May, A. D. 1975,

and now remaining on file and of record in this office.

In Testimony Whereof, *I have hereunto set my hand and affixed the seal of the State of Rhode Island, this* seventh *day of* May *A. D.* 197_

Secretary of State

4-10

State of Rhode Island, &c.

IN GENERAL ASSEMBLY

JANUARY SESSION, A. D. 1975

HOUSE RESOLUTION

RESPECTFULLY REQUESTING THE UNITED STATES ARMY CORPS OF ENGINEERS TO CONTINUE THE WATER RESOURCE STUDY OF THE PAWTUXET RIVER BASIN ESPECIALLY THE WARWICK AND NORWOOD LOCAL PROTECTION PROJECTS.

WHEREAS, Following the heavy damages suffered during the storms of March 1968 and February and April 1970, a study was undertaken to improve flood control, navigation, water supply, water quality control and allied water use of the Pawtuxet River Basin; and

WHEREAS, A comprehensive approach by Federal, state, local and private agencies to flood control management provides optimum development of water resources; and

WHEREAS, The Pawtuxet River Basin which is subject to both river and tidal floods has experienced disasterous floods in 1936, 1938, 1968 and twice in 1970; and

WHEREAS, Since the 1968 flood the entire basin has undergone significant land use changes; and

WHEREAS, The Warwick Local Protection Project will provide dikes, walls, thus, affording protection to over two hundred homes, businesses and industrial establishments; and

WHEREAS, The Norwood Project would provide a dike to afford a substantial degree of flood protection for the residents of Elmwood Avenue in Warwick; now, therefore, be it

RESOLVED, That the U.S. Army Corps of Engineers is hereby commended for their excellent work and is respectfully requested to continue the water resource study of the Pawtuxet River Basin, especially the Warwick and Norwood Local Protection Projects; and be it further

RESOLVED, That the secretary of state be and he hereby is authorized and directed to transmit a duly certified copy of this resolution to the United States Army Corps of Engineers.

State of Rhode Island and Providence Plantations

Department of State

Office of the Secretary of State

I, FREDERICK A. MASSARO - First Deputy *Secretary of State of the State of Rhode Island and Providence Plantations,* **hereby Certify** *that the aforegoing is a true* xerographic *copy of* a House Resolution (75H-6544) entitled HOUSE RESOLUTION RESPECTFULLY REQUESTING THE UNITED STATES ARMY CORPS OF ENGINEERS TO CONTINUE THE WATER RESOURCE STUDY OF THE PAWTUXET RIVER BASIN ESPECIALLY THE WARWICK AND NORWOOD LOCAL PROTECTION PROJECTS.; the same being

taken from the records in this office and compared with the original House Resolution 75H-6544 passed in the House of Representatives at the January Session of the General Assembly, A.D. 1975 on the seventh day of May, A.D. 1975 -

and now remaining on file and of record in this office.

In Testimony Whereof, *I have hereunto set my hand and affixed the seal of the State of Rhode Island, this* eighth *day of* May *A. D.* 1975

First Deputy *Secretary of State*

3-12

At a Special Meeting of the Town Council of the Town of West Warwick held on the 7th day of May A. D. 1975, all members being notified and a quorum being present the following RESOLUTION was unanimously adopted:

RESOLVED, that WHEREAS, the Natick Diversion Project proposed by the New England Division of the Army Corps of Engineers is in the best interest of the Citizens of West Warwick in that it will prevent flooding in the Flood Plain along the Pawtuxet River in a portion of U. S. Census Tract, Rhode Island 205, locally designated as Natick Flats

Be it Therefore Resolved, that the Town Council of the Town of West Warwick supports said project in its intent pending the results of a comprehensive Environmental Impact Statement on the Pawtuxet River Basin.

A TRUE COPY.

ATTEST:

Margaret E. Conlon

COUNCIL CLERK

CITY OF WARWICK, RHODE ISLAND

DEPARTMENT OF CITY PLAN
CITY HALL 02886
(401) 737-2[illegible] EXT. 53

William [illegible] George
Director

May [illegible], 19[illegible]

[illegible] John H. Mason
Division Engineer
[illegible] States Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Re: Pawtuxet River Basin Flood Project

Dear [illegible] Mason:

[illegible] that the Mayor, members of the City Council, and various [illegible] have held informal discussions on the Pawtuxet [illegible]. It is noted that the project was initiated by [illegible] Warwick as a result of the 1968 flooding. The record of the [illegible] that had the Scituate Reservoir been full when the 1968 [illegible] have increased from $500,000 to $15,000,000. [illegible] Furthermore, significant land use changes have [illegible] construction has occurred in the river basin involving [illegible], Warwick Mall (two shopping centers which presently occupy [illegible] square feet of floor space and have a total of 125 retail stores), [illegible] of the Del Rio Complex, Bulova Company, Ciba-Geigy Chemical, [illegible] industrial parks; value of real property exceeds a low of 90 [illegible] a high of [illegible]00 million with approximately 4,750 jobs in the [illegible] sectors. In addition, the City Sewerage Treatment [illegible] lies [illegible] river basin. In excess of 200 families in the Norwood [illegible] would be effected by a 100-year flood. These are salient [illegible] that [illegible] not be treated in a light manner.

[illegible] of Warwick requests that the on-going study on the Natick [illegible] with the local protection projects included be continued; [illegible] assessments be conducted, and that cost benefits be more [illegible]. As the environment assessment and cost benefit information [illegible] received, a formal finding is not being made on this [illegible] City of Warwick.

[illegible] has been presented and various options reviewed, the [illegible] Warwick will forward its recommendation. This will be done within [illegible] submission of the necessary information.

[illegible] yours,

William E. George

Recd 5-8-75

PETITION

We, the undersigned, are residents of the Belmont Park section of Norwood, in Warwick, R. I.. Although we are unable to attend the meetings on the Natick Diversion, Norwood and Warwick Projects, we would like to make it known that we would like the Army Corps of Engineers to continue with the study of these projects, as we are in great need of protection from the Pawtuxet River.

****

Linda Zuercher 59 First Ave. Warwick
Albert Zuercher 59 First Ave Warwick
Roxanne Swanson 59 First Ave Warwick
Ann E. Rachlau 45 Wingate Ave Warwick
Wm. Leonard 21 Heath Ave. Warwick
[illegible] Leonard 21 Heath Ave. Warwick
[illegible] Kelly 1746 Elmwood Ave. Warwick
[illegible] Johnston 82 First Ave Warwick
[illegible] C. [illegible] 30 [illegible] Ave Warwick

Mr & Mrs Charles [illegible] [illegible] Warwick

***** P E T I T I O N *****

We, the residents of Belmont Park, located in the Norwood section of Warwick, R. I., would like to go on record as being in favor of the Army Corps of Engineers continuing their studies of the Natick Diversion, and Norwood and Warwick Projects.

****

Betty Pierce 193 Sumner Ave. Warwick

[illegible] Della Porta 34 Sumner Ave. Warwick R.I.

Barbara L. Della Porta 34 Sumner Ave Warwick, R.I.

[illegible] Cole 14 Wingate Ave. War. R.I.

Mr. & Mrs. [illegible] Lawrence 15 King Ave. Warwick R.I.

[illegible] Anna Colucci 84 Sumner Ave.

[illegible] Sumner Ave

[illegible] 70 King Ave Warwick

[illegible] 57 King Ave Warwick

[illegible] 40 Sumner Ave Warwick

[illegible] 29 King St Warwick

[illegible] 33 [illegible] Warwick R.I.

[illegible] King [illegible]

Mr. & Mrs. James B Buttle Jr 51 King Ave

[illegible] Sumner Ave War.

Mr. & Mrs. John [illegible] Wingate Ave.

Mr. & Mrs. Burton H. Dawson 62 Wingate Ave. War. R.I.

[illegible] Schmitt 45 Sumner Ave Warwick

[illegible] Pierce 193 Sumner Ave

[illegible] 18 Wingate Ave Warwick R.I.

[illegible] 11 Wingate Ave Warwick R.I.

[illegible] Sumner Ave

[illegible] 25 Sumner Ave

[illegible] Mayer 18 King Ave.

Joe Kilduff 46 Ring Ave
Diane Kilduff 46 Ring Ave.
Mrs Elizabeth A. Flaming 115 King St
Mr [illegible] Flaming 115 King St
George Bloomingburgh 58 Iona Ave.
[illegible]
Hastings Ryellet 38 Mill St
Larry Colvin 74 Sumner Ave
Sandra Colvin 74 SUMNER AVE.
Matilda Colvin 44 Wingate Ave.
[illegible] Colvin 44 Wingate Ave

Statement read + submitted
by Sen. Joseph Walsh Dist. 15. Warwick.

The residents of Belmont Park [redacted] have a serious, legitimate complaint about flooding problems. The people of that area want and deserve protection and the city, state and federal government has an obligation to provide it.

The situation in this area is precarious because the city has allowed growth on the flood plain, the state has opened the flood gates at the reservoir and the direction of the river when Route 95 was constructed.

I have been directly involved with the residents in this area for several years. I personally got involved filling sandbags to build dikes to stop flooding several years ago. I requested that the Army Corps of Engineers come up with a program to alleviate flood problems for these people and I have stated at prior public hearings that some plan for relief must be developed.

[redacted]

Reservations have been raised concerning the proposed diversion tunnel in terms of the [illegible] for it, the cost factor and possible adverse affects on some sections of the city.

I believe that the Army Corps of Engineers should go back to the drawing boards and come up with a plan that will provide relief from normal flooding to the Belmont Park area without adversely effecting the other sections of the city.

The people of Belmont Park don't want to hurt anyone else or pollute Apponaug Cove. They simply want to protect their own homes.

The Army Corps of Engineers should consider a project that would involve construction of a series of dikes to provide relief to that area. The tunnel may not be necessary to provide relief and [redacted] I cannot condone a [illegible] that will adversely affect the residents of Greenwood living in the path of the tunnel or a plan that will pollute Apponaug Cove.

There are residents of Warwick who have serious objections to this plan. Rather than scrap the whole thing, I would like to see the Army Corps of Engineers come up with a more realistic, modest plan to provide relief to Belmonth Park without affecting the other areas.

~~In the event that no solution~~
~~No matter what solution is reached on this proposal,~~ [illegible]
of a sensible ~~plan pl~~ land use plan and new zoning ordinance to safeguard [illegible] residents from further flood damage losses due to encroachment on the flood [illegible] plain. A statewide solution is needed to encourage land acquisition, easements and tax encentives which promote wise land use.

MEMBERS OF THE ARMY CORP OF ENGINEERS, LADIES AND GENTLEMEN:

MY NAME IS DOMENICK J. ROMEO AND I PRESENTLY RESIDE AT 223 THIRD AVENUE IN CRANSTON. I HAVE LIVED IN THIS RESIDENCE SINCE 1941. FOR 66 OF MY 68 YEARS OF LIFE I HAVE ALWAYS RESIDED WITHIN A STONES THROW OF THE BANKS OF THE PAWTUXET RIVER. I OWN APPROXIMATELY 2 ACRES OF VACANT LAND FRONTING THE PAWTUXET RIVER IN CRANSTON.

I WOULD VENTURE A GUESS THAT THERE ARE FEW IN THIS ROOM WHO HAVE HAD AS MUCH EXPERIENCE OR WHO COULD SPEAK TO THE HISTORY OF THIS RIVER RELATED TO FLOODING BASED ON ACTUAL KNOWLEDGE. I REMEMBER VERY WELL THE HURRICANES OF 1938 AND 1954. EVEN DURING THESE MOST SEVERE WEATHER CONDITIONS, IT IS IMPORTANT TO NOTE THAT THE PAWTUXET RIVER DID NOT CREATE SERIOUS FLOODING TO AREAS ALONG ITS FULL LENGTH.

MOST RECENTLY, IN AN EFFORT TO CAPITALIZE ON THE BASIC FEARS THAT MOST HUMANS HAVE OF FLOODS AND HURRICANES, RESIDENTS OF THE BELMONT PARK AREA IN WARWICK AND THE CLEVELAND PARK SECTION IN CRANSTON, WERE INSTRUCTED TO MOVE DURING THE LAST HURRICANE WARNING. ONE MUST ASK A BASIC QUESTION --- WAS THERE ANY INTENT

ON THE PART OF ANY LOCAL OFFICIALS OR THE ARMY CORP OF ENGINEERS TO CREATE A STATE OF PANIC IN THE MINDS OF THESE RESIDENTS IN ORDER TO SUPPORT A 59.3 MILLION DOLLAR PROJECT?? IT WOULD APPEAR TO ME THAT EFFORTS IN THE FORM OF PUBLIC RELATIONS WORK ARE WELL UNDER WAY TO CONVINCE HOME OWNERS THAT UNLESS THEY SUPPORT THIS 59.3 MILLION DOLLAR PLUS PROJECT THAT THEIR LIVES AND PROPERTY WILL BE IN CONSTANT DANGER FROM FLOODS AND OTHER NATURAL DISASTERS. UTILIZING SCARE TACTICS IS A VERY OLD TECHNIQUE USED TO GATHER SUPPORT. AS A LAYMAN, I DARE SAY THAT FOR A FRACTION OF 59.3 MILLION DOLLARS, ALL FLOOD PRONE LAND AND IMPROVEMENTS THEREON ALONG THE BANKS OF THE PAWTUXET RIVER COULD BE PURCHASED AND DEVELOPED INTO RECREATIONAL AREAS AND WILD LIFE SANCTUARIES TO BENEFIT ALL THE PEOPLE.

IT IS IMPORTANT FOR LOGICAL AND PROPERLY MOTIVATED TAX PAYERS NOT TO BE CARRIED AWAY REGARDING (QUOTE) "FACTS" PROVIDED BY THE CORPS WHICH HAS A VESTED INTEREST IN PROMOTING ITS OWN EXISTENCE!

ANOTHER IMPORTANT FACT IS THAT HOME OWNERS ALONG THE RIVER ARE ENTITLED TO QUALIFY FOR FLOOD INSURANCE. IMAGINE THE COST

OF FLOOD INSURANCE PREMIUMS FOR RELATIVELY FEW PEOPLE ALONG THE PAWTUXET RIVER AS COMPARED WITH THE COST OF CONSTRUCTION TUNNELS AND DIKES AND OTHER ECOLOGICAL MONSTROSITIES CONCEIVED BY THE ARMY CORPS OF ENGINEERS --- AGAIN, IN THEIR INTEREST TO (QUOTE) "PROTECT THE PUBLIC" !!!

WITHIN ONE YEAR, THE PRICE TAG FOR THIS PROJECT HAS RISEN FROM 30 MILLION TO 59.3 MILLION. THE TOTAL COST CAN BE EXPECTED TO BE MUCH HIGHER. THE "EVENING BULLETIN" IN THE SEPTEMBER 21, 1976 EDITORIAL, SERIOUSLY QUESTIONED NOT ONLY THE COST OF THIS PROJECT, BUT THE CONSEQUENCES OF DUMPING DIRTY RIVER WATER INTO THE RELATIVELY CLEAN APPONAUG COVE. THOSE OF US WHO WISH TO LEAVE A LEGACY OF ENVIRONMENTAL IMPROVEMENTS TO OUR CHILDREN ALSO QUESTION THE MERITS OF THIS ACTION.

IN CONCLUSION, I WOULD ASK THAT ALL RESPONSIBLE INDIVIDUALS WITHIN THIS ROOM CONSIDER THIS PROJECT TO BE INAPPROPRIATE, EXPENSIVE AND WITHOUT ANY REDEEMING MERIT! THIS PROJECT, BY THE ARMY CORPS OF ENGINEERS, HAS AS MUCH LOGIC IN PROTECTING PEOPLE FROM FLOODING AS FILLING IN THE GRAND CANYON WOULD TO PROTECT PEOPLE FROM FALLING IN !!!

THANK YOU.

SUMMARY OF OCTOBER 1976 PUBLIC MEETING

The next public meeting was held on 14 October 1976. Presentations were made by NED representatives regarding the present status of the proposed flood reduction plan for the lower Pawtuxet Watershed. At this time the selected plan consisted of the Natick Diversion in combination with the Warwick Local Protection Project plus regulatory measures and future non-Federal programs. Regulatory measures were primarily the application of the National Flood Insurance program in all basin zones throughout the watershed. The future action program would include the proposed Big River Reservoir adapted to provide additional flood control storage.

A brief overview of the history of the study from its initiation in 1969 to its present status was given as well as an explanation of the technical aspects of the selected plan. The environmental and socio-economic impacts of the structural elements were also given.

In the public comment portion of the meeting, Maureen Maigret, State Representative from District 37, expressed opposition to the proposed plan on the grounds that the cost was too high as well as the potential harmful affects imposed on Apponaug Cove. Excess coliform bacteria and the decrease of salinity in the cove were her major environmental concerns. She also voiced opposition to the tunnel blasting and traffic hazards.

A representative from the 35th District, J. Friedemann, cited a total absence of public support for the project with the major factor being the cost. The city would not be able to come up with the $800,000 allocation toward the project or the $17,000 annual operating charges. A bond issue or a budgetary line item would be required and neither was in the foreseeable future. As an alternate, Mr. Friedemann proposed better land-use planning implemented by a sound and practical zoning and sub-division regulation plan. This could be at a cost which would not burden the tax payers. In the area of the projects ecological impact, he stated that the extent of pollution as well as affected species of marine life could not totally be predicted by the computerized model.

A city planner, representing Providence, presented the official statement of the city of Providence. The city opposed the project for two main reasons. It ignores available remedies that could more immediately eliminate flood damages and secondly, the proposal substitutes highly expensive measures for less expensive, equally effective measures. In relation to the first, he cites that the project will not be operational before 1985. Therefore, it would not afford projection to Warwick or Cranston for nine years. As an alternate, less expensive, solution, the river could be cleared of

structural as well as non-structural obstructions which inhibit the flow of the channel.

Removals could include obsolete structural foundations, and demolished dams and bridges as well as trapped sediments and industrial sludge like those accumulated in the backwater reaches of Broad Street Dam. He recognized as a potential flood threat the concrete that juts across the spillway of the Broad Street Dam. Additional flood control storage at the Scituate Reservoir should be investigated more thoroughly in conjunction with the above mentioned measures.

The planning director of the city of Warwick representing Mayor Eugene J. McCafrey accepted the plan of action regarding regulatory measures in both flood plain and non-flood plain areas, adherence to the 100-year flood plain zoning supported by building code restrictions, continued participation in the National Flood Insurance Program, and the construction of the proposed Big River Reservoir. Support was also given to the construction of the local protection project as enumerated for Warwick. The Natick Diversion was opposed because of the economic cost-benefit ratio involved. Recommendations were also made for the removal of the previously mentioned retaining wall at Broad Street Dam and for the straightening and deepening of the channel from the Mall to the mouth at Pawtuxet Village.

Former Governor John Chafee expressed concerns over environmental impacts on Apponaug Cove and to the expense of the Natick Diversion.

The planning director of the city of Cranston, speaking on behalf of Mayor James Taft, also objected to the high cost of the diversion as well as the environmental impacts urging the Corps to re-examine alternatives to the tunnel that could be implemented at a cost acceptable to the taxpayers.

The city of Warwick's council president objected to the tunnel on the basis of cost. Doubt was raised as to the passage of a bond which would fund the project.

A councilman from the city of Warwick was concerned about the Belmont Park Section suggesting that a series of dikes be substituted for the proposed tunnel. He stated that the Corps has overdesigned a project that will not be completed for ten years. The representative from Ward 2, District 30, also was in favor of a dike to protect the Belmont Park Area in lieu of a tunnel.

An employee of the Environmental Protection Agency (who spoke on his own personal views as opposed to the agencies) objected to the environmental aspects of the project and proposed a plan of

acquisition as an alternative. He took issue toward the computer model developed to evaluate the affects of changes in salinity due to the mixing of fresh and salt water. This, in his opinion, could wipe out an entire species in larval form. He also pointed out the health hazzard caused by coliform intrusion possibly resulting in the closing of areas of Apponaug Cove and Greenwich Bay for shellfishing. A representative from the Rhode Island Association of Conservation Commmissioners reiterated acquisition as an alternative to the proposed plan. He objected to the term 'standard project flood' since no reference of its frequency was mentioned in the interim report. A sensible judgement concerning this proposal cannot be made when the chance of ocurrence has never been defined.

A student at Brown University, researching the question of flood protection in the Pawtuxet Basin, stated that the Environmental Impact Statement was inadequate in terms of the requirements specified by the National Environmental Policy Act. The system of accounts used to choose the Natick Diversion as the most feasible flood protection project was incomplete. There was no logical discussion of the alternative plans in addition to factual information to support one choice over another. He proposed that the Big River Reservoir Plan offers a cost alternative that seems highly feasible. Also, the marginal benefit cost ratio cast serious doubt on the economic feasibility of the project. Environmental concerns were also expressed by this student.

The Senator from District 15 of the city of Warwick, Joseph Walsh, objected to the selected plan. He stated that the residents of the Belmont Park Section have a serious, legitimate complaint about the flooding and deserved protection implemented by the State and Federal government. In lieu of the Corps selected plan, a series of dikes should be constructed in order to provide the necessary relief in conjunction with a sensible land use plan.

One of the residents was supportive of what the Corps was trying to do in the basin, not so much that they supported a diversion plan but pleaded for dike protection at the Belmont section. They were candid enough to say that city officials certainly knew four years ago what the Corps was planning. All other area residents opposed the diversion tunnel in terms of the necessity for it, the cost factor and the possible adverse affects on some portions of the city, especially with relation to the environment, the pollution of Apponaug Cove, and the danger with regards to tunneling under homes.

CORRESPONDENCE FROM 1976 PUBLIC MEETING

Mayor James L. Taft, Jr. Executive Chamber/City Hall/Cranston, Rhode Island 02910

October 14, 1976

Col. John P. Chandler
Army Crops of Engineer
Department of the Army
424 Trapelo Road
Waltham, MA

Dear Col. Chandler:

As Mayor of Cranston I want to register my strong opposition to the Corps of Engineers proposal to build a flood diversion tunnel under part of the Pawtuxet River.

I believe the project, which is [illegible]stimated to cost nearly $60 million, is far too expensive. Ba[illegible] what benefits the Corps projects from this plan, the cost is [illegible]o extravagant.

We must also take into consideration the fact that [illegible] project began immediately it would not be finished [illegible] Since the Corps needs Congressional approval befo[illegible] begin, it is obvious the project will not get underway f[illegible] many years. During that waiting period I suspect noth[illegible] bring about an immediate solution to problems tha[illegible] be cause[illegible] by Pawtuxet River flooding.

Just as importantly, the tunnel will produc[illegible] of Apponaug Cove and Greenwich Bay. During the cons[illegible]od of 10 or more years the river's ecology and that of [illegible] waters [illegible] which it flows will also be harmed. I am not convinced that Corp[illegible] has assessed the full impact of the industry in these waters, th[illegible] tunnel during its construction phase and afterwards could pose a serious threat to a viable new industry.

I urge the Corps to re-examine alternatives to the tunnel. The properties along the river should be protected and can be at a cost that is acceptable to the taxpayer and in a manner that will enhance, not destroy the environment.

Sincerely yours,

James L. Taft, Jr.

James L. Taft, Jr.
Mayor

JLT:jv

Printed on 100% recycled paper to save our woodlands, our air, and our water

October 14, 1976

TO: Department of the Army Corps of Engineers
New England Division
Waltham, Massachusetts

FROM: Robert J. Sullivan, 27 Marcy Street, Cranston, Rhode Island

SUBJ: Pawtuxet River Flood Protection

I should begin by commending the Corps of Engineers for some very worthwhile projects which it has undertaken. The hurricane barriers in New Bedford and Providence are outstanding examples. The Fox Point Hurricane Barrier was built at a cost of $16,000,000 while the New Bedford facility cost $18,000,000. These projects afford protection from very real threats and have very favorable cost/benefit ratios.

In contrast to the above projects, the project proposed for the Pawtuxet River would cost nearly four times as much and would provide lesser benefits. I consider the cost benefit ratio of the project to be very unfavorable. For this reason I am opposed to the project in its present form.

The Corps of Engineers has not demonstrated that there has ever been a Pawtuxet River flood which even approached the severity which would justify the proposed project. The most recent flood occurred in 1968 and caused approximately $200,000 damage.

According to the Corps of Engineers (Pawtuxet River Watershed Interim Report, U. S. Army Corps of Engineers, 1976.), 471 buildings are susceptible to the type of flood which could be expected to occur once in a hundred years.

The project would cost at least $59,300,000. At this rate we would be spending $[illegible] for each structure protected. The Corps of Engineers mentions a more severe flood (Standard Project Flood) which apparently would occur even less frequently than once in a century. In this extreme case, 1856 structures would be protected. The protection costs per structure would then be $31,950. In either case, the cost/benefit ratios are unfavorable.

A more [illegible] plan would be to: 1) prohibit future construction on the flood plain; 2) phase out existing residential use of the flood plain; and 3) provide [illegible] highly concentrated commercial property with dikes of other [illegible] protective structures. Such a plan would be far less expensive and would provide adequate flood protection.

Injury or loss of life is a vital factor which must also be considered. I find no reference to this in the [illegible] Report of the Corps of Engineers. My personal knowledge of the region leads me to the conclusion that Pawtuxet River flooding has never caused fatalities. I would judge that the dangers to workers digging the tunnel would greatly outweigh the personnel dangers which future flooding could produce.

I will close by stating that I consider flood protection essential in the matter in question, however, the Corps of Engineers plan far exceeds what is necessary.

State of Rhode Island and Providence Plantations

REPRESENTATIVE
MAUREEN E. MAIGRET
232 Vancouver Avenue
Warwick, Rhode Island 02886

Room 326 State House
Providence, Rhode Island 02903

Committee on Labor

House of Representatives

October 14 1978

John P. Chandler
Colonel, Corps of Engineers
Division Engineer
Department of the Army
New England Division, Corps of Engineers
Waltham Massachusetts

RE: Pawtuxet River Watershed. Interim Report
Final Stage Public Hearing Statement

I wish to express my opposition to the Army Corps of Engineers' proposed flood management program referred to as the NATICK DIVERSION.

I oppose the project because of the extremely high cost as well as the adverse environmental effects the diverted waters would have on Apponaug Cove and Greenwich Bay.

It is important to note that despite the predicted cost of 59 million dollars, the effectiveness of the NATICK DIVERSION on flooding downstream of the Meshanticut Brook gradually diminishes, and due to tidal influences on the river, the DIVERSION would only reduce flood stages for a standard project flood about 3 ft. at the Warwick Industrial Park Site, although the predicted water level would be 12 ft. higher than the March 1968 flood.

It is also important to note that the study emphasizes the indirect economic benefit of making available for development some 200 acres of presently undevelopable land located within the floodway of the main stem. Increasing development within the floodplain, even if the DIVERSION were to be built, would seem to be poor land use planning, especially since the DIVERSION would not be 100% effective.

2

John P. Chandler
October 14, 1976
Page 2

As planned, the NATICK DIVERSION will cause environmental damage to Apponaug Cove and Greenwich Bay. Both Apponaug Cove and Greenwich Bay are important areas for recreational fishing, while the Bay is an important source of commercial shellfishing (an estimated $1 million/year industry). The Environmental Statement suggests that future plans for the Pawtuxet River can eliminate the problem of pollution of the Cove and Bay with coliform bacteria from the diverted river water. This, I believe, is an unwarranted assumption, especially since no data is available at the present time concerning River pollution from non-point sources. I am specifically referring to run-off pollution which would increase significantly during flooding. The Environmental Statement did not appear to address this problem which is scheduled to be investigated by a Task Force of the 208 Study.

The second area of environmental concern is the effect of the decreased salinity on marine life. A once every 15 year event is predicted to result in the loss of the year class in all the Cove and 10% of the Bay while a less than once in 100 years event is predicted to effect 70% of the Bay causing mortality for some adult species and eliminating early life stages for many. I object to both the potential public health effects created by increasing the pollution in the Cove and Bay and to the possible destruction of marine life.

My final points of objection relate to concerns expressed to me by residents in my district relative to the possible harmful effects on their homes by the drilling and blasting that would occur; the possible decrease in property values; and the very serious traffic hazards which would occur in the Apponaug area during construction.

I realize that the flooding of the Pawtuxet River is a serious problem which we must find a solution for, and therefore recommend further study of the Alternative labeled "D", the Environmental Quality Plan consisting of the Local Protection Projects, regulatory measures, and upstream future action measures for reservoir management.

Respectfully submitted by,

Maureen E. Maigret

Maureen E. Maigret
Representative - District 37

MEM:vlh

APPONAUG HEIGHTS COMMUNITY ASSOC.
7 Gilbert St.
Warwick, R.I.

October 14, 1976

Colonel John P. Chandler
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Chandler:

The Apponaug Heights Community Association, which is composed of sixty families residing on Gilbert and adjoining streets, wishes to go on record with the City of Warwick and the Army Corps of Engineers as being strongly opposed to the proposed Natick Diversion Flood Plan in its present format.

As homeowners and taxpayers, the members of the Association are greatly concerned that the city's portion of the approximately 60 million dollar construction price, in addition to an annual outlay of $97,000 tax dollars for amortization and maintenance is too great a burden for the citizens of this city. At a time when the city is straining to eliminate deficit spending and achieve a balanced budget and at the same time hold the line on real and personal property taxes, it appears to the Association that a commitment to this project can only result in an inability to maintain a balanced budget coupled with tax rate increases.

The Association is also concerned with the findings of the Environmental Impact Study and the damage this project would cause to the Apponaug Cove.

There are many other concerns which must be addressed, not the least of which is potential damage to property substructures due to a change in the water table and vibrations from drilling, boring or blasting.

In summary, the Association feels that the present plan is not in the best interests of our residential area and recommends that an alternative plan be proposed which will serve the interests of all the citizens of Warwick.

Sincerely,

Richard A Block

Richard Block, President
RB/bg
Copies: Warwick Planning Board, Mayor,
Governor, R. I. Congressional Delegation

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
New England Area Office
P. O. Box 1518
55 Pleasant Street
Concord, NH 03301

October 20, 1976

Colonel [illegible] Chandler
Division Engineer
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Colonel Chandler:

This letter is our statement for the Public Hearing on Water and Related Land Resources Investigations for the Pawcatuck River and Narragansett Bay Drainage Basins, Pawtuxet River Watershed. Please include it in your records of the hearing. The hearing was held at Warwick, Rhode Island on October 14, 1976.

This Service advises that the recommended plan may significantly alter the aquatic environment and adversely affect the finfish and shellfish resources of Apponaug Cove and Greenwich Bay. In addition, the anadromous fishery potential of the Pawtuxet Basin may be forfeited.

Further studies will be required to determine the effects of the proposed project on the fish resources of the area and also water quality of the cove and bay. The Service recommends that your report be modified to provide for further studies of project effects on fish habitat and water quality, and for such reasonable modifications to be made in project facilities for the conservation and development of fishery resources as may be found necessary and as may be agreed upon by the Director of the U.S. Fish and Wildlife Service and your agency.

We will supply you with our Conservation and Development report for this project on or before October 29, 1976.

Sincerely yours,

Melvin R. Evans

Melvin R. Evans
Field Supervisor, NEAO

JAMES L. TAFT JR.
MAYOR

CONSERVATION COMMISSION
... OFFICE
CITY HALL
CRANSTON, RHODE ISLAND
PHONE 461-...

October 28, 1976

Colonel John P. Chandler
Department of the Army
New England Division
Army Corp of Engineers
424 Trapelo Road
Waltham, MA 02154

Re: Pawcatuck River and Narragansett Bay Drainage Basin - Pawtuxet River Watershed Study

Dear Colonel Chandler:

The members of the Cranston Conservation Commission wish to express on record their opposition to the proposed Natick Diversion tunnel on the Pawtuxet River. While the Commission endorses many of the other recommendations brought forth in your comprehensive study, particularly the need for better management of flood control programs, we cannot support the recommended Natick Diversion tunnel.

We would suggest that the Army Corp in further study carefully consider the following kinds of alternatives to flood control in the Pawtuxet basin:

- -Develop a flood plain management program which maximizes non-structural solutions
- -Negotiate an optimal flow regime
- -Channel improvement program to allow large volumes of water to be contained in the channel without flooding. Clearance of obstructions in the river bed and restoration of the natural river bed are minimum actions here.
- -Strict compliance and enforcement with local flood plain zoning ordinance as defined under the National Flood Insurance Program. Related regulations governing development should reinforce the local flood control ordinance.
- -Establishment of local sedimentation and erosion control ordinances
- -Improved water storage of Scituate Reservoir; and
- -Design of the Big River Reservoir for flood surcharge storage.

Many other constructive suggestions were heard at the hearing of October 14, 1976. The Cranston Conservation Commission, the many citizens and public officials present at that hearing, is firmly opposed to the construction of the Natural Diversion and further asks that the Corp restudy this important matter.

Sincerely yours,

Aldena Caldarone

(Mrs.) Aldena Caldarone
Chairperson, Conservation Commission

AC:sl

Cranston Plant

CIBA-GEIGY Corporation
P.O. Box 2055
Providence R.I. 02905
Telephone 401 941 3000

Shipping Address:
180 Mill Street
Cranston, R.I.

CIBA-GEIGY

October 2? 197?

Colonel John P. Chandler
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts, 02154

Dear Colonel Chandler:

This letter and the attached written statement are in response to the "Announcement of Late Stage Public Meeting" concerning proposed flood control measures for the Pawtuxet River which was issued on September 15, 1976.

Our Corporation's concerns about the effect of the proposed measures are summarized on the attached written statement. Consideration of these concerns by the Corps of Engineers is appreciated.

Very truly yours,

CIBA-GEIGY CORPORATION
Cranston Plant

Richard T. Pincince

Richard T. Pincince
Engineering Manager

RTP:cm
Enclosure

Basis for Opposition to Natick Division - Warwick

Local Protection Project

1. While the project, as proposed, would lower the level of flood waters on Ciba-Geigy's property in Cranston in the event of a 100 year storm, it would not prevent flooding of the Corporation's manufacturing buildings or effluent treatment facilities site.
2. The installation of dikes on the Warwick side of the River would protect Ciba-Geigy's facilities in Warwick. In the process, all of the Corporation's Warwick property would no longer be in the "flood plain". In the event it were necessary to install new facilities on the Corporation's Cranston property, compensation, presumably in the form of earth removal, would have to be made from the Cranston property to meet the zero displacement provision required by the Rhode Island Department of Natural Resources. With the present limited land availability on the Corporation's Cranston property, this situation imposes a severe restriction. It would make it virtually impossible to install additional manufacturing or effluent treatment facilities in the future.

10/12/76

CARROLL, KELLY & MURPHY
COUNSELLORS AT LAW
326 INDUSTRIAL BANK BUILDING
PROVIDENCE, RHODE ISLAND 02903
AREA 401-331-7272

JOSEPH A. KELLY
JAMES E. MURPHY
ROBERT K. ARGENTIERI
C. RUSSELL BENGTSON
DENNIS S. BALUCH

November 12, 1976

Col. John P. Chandler
Division Engineer
New England Division Corps.
 of Engineers
Department The Army
424 Trapelo Road
Waltham, Massachusetts 02154

Re: Pawtuxet River - Natic Diversion Tunnel

Dear Col. Chandler:

Please be advised that I represent the Pawtuxet River Authority. At its meeting held on November 8, 1976, the Authority voted to have me communicate its sentiments to you regarding the Natick Diversion Tunnel.

After much study and deliberation, the Authority rejected the Tunnel as the most practical way to control flooding along the river.

The Authority suggests the following as possible alternatives which should be studied further: dredging the river to remove accumulated rubble, sludge, and sediments; removal of obsolete dams and bridges (including the Broad Street Dam); removal of obsolete and demolished man-made objects which are encroaching on the river; remodeling and rehabilitating certain

of the dams on the river; and channel straightening.

The Authority felt that these alternatives would not only benefit the lower reaches of the river, but the entire river as well. Furthermore, these alternatives would best "restore the river to its former status as a recreational asset" as mandated by the General Assembly for the State of Rhode Island when it created the Authority.

Very truly yours,

C. RUSSELL BENGTSON

CRB:mas

cc: Mr. Emile LaFleur
Mr. Anthony Venetetuolo
Mr. Rene Dionne

COMMENTS ON 1976 E.I.S.

Eugene J. McCaffrey, Jr.
Mayor
Executive Chamber / City Hall / Warwick, Rhode Island 02886

October 13, 1976

Colonel John P. Chandler
Division Engineer
Corps of Engineers
Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Re: Pawtuxet River Basin Flood Project

Dear Colonel Chandler:

Please be advised that the Pawtuxet River Watershed Interim Report and Draft Environmental Impact Statement, dated October 1976, which were prepared by the Corps of Engineers have been reviewed. As these investigative studies deal with complex natural resources of our region, you have undertaken a massive comprehensive overview that affects several communities in the Pawtuxet River basin of the State of Rhode Island. You are to be congratulated on the attempt to accommodate growth and provide for economic development while trying to protect the natural resources. It is an awesome responsibility that should direct where one in the Pawtuxet River Basin lives, shops, plays, and works now and in the future.

It is noted that the Pawtuxet River Basin Flood Project was initiated by the City of Warwick as a result of the 1968 flooding. As contemporary history shows, had the Scituate Reservoir been full when the 1968 flood hit, "damages would have increased from \$500,000 to \$15,000,000 or a 30-fold increase." Furthermore, significant land changes have occurred. Additional construction has occurred in the river basin involving Midland Mall, Warwick Mall (two shopping centers which presently occupy 1,300,000 square feet of floor space and have a total of 125 retail stores), 488 apartments of the Del Rio Complex, Bulova Company, Ciba-Geigy Chemical, and in two industrial parks; value of real property exceeds a low of 90 and approaches a high of 100 million with approximately 4,750 jobs in the retail and manufacturing sectors. In addition, the City Sewerage Treatment Facility lies in the river basin. In excess of 200 families in the Norwood area could be affected by a 100-year flood. These are salient characteristics that cannot be treated in a light manner.

Colonel John P. Chandler
Page 2
October 14, 1976

To address the above flooding problems in the Pawtuxet River Basin. the Corps has published a recommended plan for implementation as a total system. This system consists of structural measures (Natick Diversion Tunnel and local protection projects in Warwick) and an action program dealing with existing Scituate Reservoir and proposed Big River Reservoir plus nonstructural measures (national flood insurance program, and code measures).

Based on the information on hand at the present date, the following steps of the recommended plan are acceptable:

(1.) Regulatory measures in both flood plain and non-flood plain areas to alleviate flooding problems.

(2.) Strict adherence to the 100-year flood plain by zoning supported with building code prohibition. No appeals except to the judiciary (Superior Court) would be allowed.

(3.) Continued participation by the City of Warwick in the National Flood Insurance Program.

(4.) Construction of proposed Big River Reservoir by the State of Rhode Island to meet the water supply needs of the metropolitan area-both in terms of quantity and quality for 1985-90 period. It should be noted that Warwick's demand for water for 1990 projected population can not be met by its present suppliers, Kent County Water Authority or Providence Water Supply Board. However, this city is not alone in this aspect, as the East Bay communities have the same need. Therefore, Big River Reservoir can be advanced exclusively for water supply purposes; yet it can in a secondary manner serve as additional flood control storage.

(5.) Construction of the local protection project as enumerated for Warwick, with possible additional height to the dikes for added protection.

(6.) A 2½ to 3½ foot raising of the Scituate Reservoir could provide additional flood storage area which is not part of the recommended Corps plan of implementation. However, it has been estimated that the

Colonel John P. Chandler
Page 3
October 14, 1976

> additional flood storage area of Big River in Scituate, as proposed above, would provide [illegible] percent of the flood control provided by the Natick Diversion.

Therefore, it is obvious that based on the above data, the Natick Diversion portion of the recommended plan for implementation [illegible] opposed because of the economic cost benefit ratio involved.

Physical items of oversight in the study that warrant consideration include:

a. Removal of the large, winged concrete retaining walls at Pawtuxet Village in Warwick that acts as an obstruction to the Pawtuxet River.

b. Increase the size and height of the dikes and wall in the local protection program for the Warwick area.

c. Straighten and deepen the Pawtuxet River from the Mall location to its mouth at Pawtuxet Village.

Your serious attention to these features could provide study alternatives not yet under consideration. The City of Warwick desires more study prior to a dismissal of the endeavor. Your cooperation is solicited and appreciated.

Yours very truly,

Eugene J. McCaffrey, Jr.

EJM:mp

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

COASTAL RESOURCES MANAGEMENT COUNCIL
83 Park Street
Providence, R.I. 02903

October 13, 1976

Mr. Joseph L. Ignazio
Chief, Planning Division
Department of the Army
New England Division
Corps of Engineers
Waltham, MA 02154

Dear Mr. Ignazio

The Coastal Resources Management Council is legislatively charged with planning for and managing the coastal resources of Rhode Island. The Council is concerned about the potential impacts of the "Natick Diversion" as described in the Pawtuxet River Watershed Interim Report, Draft Environmental Impact Statement. After a staff review of the report, the Council feels that certain questions remain to be answered by the Corps before the Council can put foward a position on this development.

I. General Questions

1. We question the advisability of encouraging further development in the flood plain.

2. We are uncertain as to how the allocation of $60 million for the "Natick" project will affect funding of other, perhaps more valuable Corps projects, in Rhode Island.

II. Calculations and Assumptions for the Cost/Benefit Estimate

1. Section 1.22 refers to Table I-1 which is purported to show benefit-cost figures. Our copy of EIS did not have this Table.

2. Figures 1-4, 1-5 indicate the tunnel may be full of water much of the time, unless pumped out, as suggested in Section 1.17. Have these machinery costs been considered in benefit-cost evaluation?

3. According to Section 1.22 the project life is 100 years. How would a 40 year life change the benefit cost figures? Did the 100 year life calculations have machinery replacement in them?

4. Sections 2.81 to 3.03 describe present development in the flood prone area. Table VI-5, preceeding Section 6.42, indicates 88% of flood damage is experienced by industrial and commercial sectors. As one of the alternatives, why wasn't relocation of industry to other sites considered? Has industry been queried as to their long range plans, i.e., if they plan to move in 10 years, should their protection be included in benefit-cost estimates?

5. Sections 4.04 to 4.08 indicate that some of the benefits to be realized concern the creation of areas for development. Is this feasible? Is it wanted? Section 4.08, especially shows land valuations and job expansion potential. Are these figures good estimates? Were they used in benefit-cost calculations?

III. In the discussion concerning the diversion tunnel certain questions arose;

1. Section 6.09 indicates tunnel construction has not been fully determined. How can the costs of construction be estimated?

2. We wonder about safety devices and procedures at the intake end of the diversion. We worry about small boys in boats etc., or swimmers in summer.

Mr. Joseph L. Ignazio
October 13, 1976
Page three

3. We wonder about the tunnel stability during earth quakes and tremors of the 1:100 year type. We did not notice that the subject of geologic hazards had been addressed at all.*

4. We are concerned about the biological impacts of anaerobic water being released into Greenwich Bay (1.17).

5. We wonder about the operation of the tunnel and pumps during the time of the year when ice floes may be present in the river. During the February-March period when ice can be present and the winter storm period exists, is the time of our concern.

6. Sections 4.60-4.72 discuss the computer model. We accept the assumption that in the near field the outflow will be a thoroughly mixed single layer flow. We are concerned in this region about bottom scouring, suspended sediment, and turbidity effects on benthic biota. In the far field we suspect two layer flow will exist, with outflow fresher water riding over saline bottom water. Although net flow out may be as stated, we are concerend with gross flow velocities in the two oppositely directed layers. A related problem which requires attention is the effects which stratification would have on temperature and oxygen in bottom water and the discharge of pollutants from Greenwich Bay.

7. Greenwich Bay is an already nutrient rich environment. The implications of adding the extremely nutrient rich waters of the Pawtucket River to the Bay need to be addressed.

IV. Specific Comments

Chapter 2. Environmental Setting Without Project

2.41 Mud snails (Ilyanassa obsoleta, not Nassarius) are probably less important to birds than are other snails, small bivalves and amphipod crustaceans.

*The Georges Bank EIS, Volume 4, includes a map of geologic hazards. There appears to be an earthquake epicenter within the project line.

AD-A105 823 CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV F/G 13/2
BIG RIVER RESERVOIR PROJECT - PAWCATUCK RIVER AND NARRAGANSETT --ETC(U)
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6 OF 9
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Chapter 3.

3.02 A map indicating the primary impact area would be helpful.

Chapter 4.

4.12 We question whether adequate attention has been given to construction impacts. We are concerned about such things as sediment loads, spilled fuel, high pH runoff from concrete. These issues must be addressed so that measures to mitigate impact can be undertaken.

4.58 We question the validity of the conclusion that water quality of Apponnaug Cove will not be affected (dissolved O_2, suspended sediments and temperature). The addition of sediments, particularly important after storms, will undoubtedly affect these parameters.

4.60 We feel the impacts of reduced salinity regime should be more fully discussed. Significant salinity reductions may occur over 5 day periods. We feel this is potentially very important.

4.61 Do these calculations consider the effects of leach field flooding?

Chapter 6.

6.24 We strongly believe the alternative plans of No Action and Regulatory Measures should be given further consideration.

We thank you for the opportunity to review this project and look forward to continued cooperation and coordination with the Corps of Engineers.

Sincerely yours

John A. Lyons

John A. Lyons, Chairman
COASTAL RESOURCES MANAGEMENT COUNCIL

dlz

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VIRGINIA 22092

OFFICE OF THE DIRECTOR

In Reply Refer To:
EGS-ER-76/965-MS760

Mr. Joseph L. Ignazio
Chief, Planning Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

We have reviewed the draft environmental statement for the Pawtuxet River Watershed Study.

It is noted that the additional volume of water going into Apponaug Cove will not cause significant flooding beyond the level which is presently experienced from tidal flooding (p. 4-9, par. 4.49). However, the effects of flooding on areas adjacent to Apponaug Cove resulting from maximum discharge of Natick Diversion (13,000 cubic feet per second) during worse-case conditions of storm-generated incoming tides within the Cove should be addressed.

Thank you for the opportunity to comment on the environmental statement.

Sincerely yours,

Director

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

United States Department of the Interior
BUREAU OF MINES
4800 FORBES AVENUE
PITTSBURGH, PENNSYLVANIA 15213

ER 76/965

November 3, 1976

District Engineer
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

Re: Review of Draft Environmental Impact Statement for Pawtuxet River Watershed Study, Kent and Providence Counties, Rhode Island

We have reviewed the subject statement. The project is located nine miles southwest of the City of Providence, and entails construction of a 13,000 foot floodwater diversion tunnel and assorted dikes, floodwalls, and other flood control structures.

The geology of the affected area is the Rhode Island formation, consisting of sandstone, lithic graywacke, dark shale, and conglomerate. The area has limited resources and production of stone and sand and gravel, but one sand and gravel pit located in the floodplain would apparently benefit from the proposed action. Additionally, the "floodproofing" of several major highways, including Interstate 95, may improve minerals transport in the area. No adverse impact on mineral production or resources is anticipated.

The statement contains no geologic description or mineral production or resources assessment. Inclusion of such material would facilitate the future review and evaluation of this project's Final Environmental Impact Statement.

Sincerely yours,

Robert D. Thomson

Robert D. Thomson, Chief
Eastern Field Operation Center

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

Federated Rhode Island Sportsmen's Clubs Inc.

INDIVIDUAL MEMBERSHIPS OVER 15,000

JOHN F. DEMING, *President*
40 Harrington Road
North Kingstown, R.I. 02852

ROBERT MURRAY, *Treasurer*
153 Potter Street
Cranston, R.I. 02910

ANNE D. HOLST, *Secretary*
P.O. Box 125
East Greenwich, R.I. 02818

AUDUBON SOCIETY OF RHODE ISLAND
BLACKSTONE VALLEY SNOWMOBILE CLUB
BLACKSTONE VALLEY STRIPER CLUB
BLUE WATER SPORTSMEN INC
BRADBURY FOX HOUNDS INC
BRISTOL COUNTY BEAGLE CLUB
CRANSTON FISH AND GAME ASSOC INC
CUMBERLAND BEAGLE CLUB
EAST BAY ANGLERS INC
EAST WARREN ROD AND GUN CLUB INC
FUR FEATHER AND FIN CLUB INC
GENEVA SPORTSMENS CLUB INC
GLOCESTER LIGHT INFANTRY
GLOCESTER ROD AND GUN CLUB
JOHNSON POST ANGLERS
LITTLE RHODY BEAGLE CLUB INC
MANVILLE SPORTSMENS ROD AND GUN CLUB
MASSASOIT GUN CLUB
NARRAGANSETT GUN CLUB INC
NARRAGANSETT PIER SPORTSFISHING ASSOC
NARRAGANSETT SALT WATER FISHING CLUB
NINIGRET ROD AND GUN CLUB
NOOSENECK HILL CLUB
NORTHERN RHODE ISLAND SPORTSMENS CLUB
PROVIDENCE ROD [illegible] CLUB INC
REEL MENS SPORTING CLUB
RHODE ISLAND COON HUNTERS ASSOC INC
RHODE ISLAND FAMILY CAMPERS ASSOC
RHODE ISLAND FEDERATION OF RIDING CLUBS INC
RHODE ISLAND FISH AND GAME PROTECTIVE ASSOC
RHODE ISLAND LEAGUE OF ANGLERS
RHODE ISLAND MOBILE SPORTFISHERMEN
RHODE ISLAND STATE RIFLE AND REVOLVER ASSOC INC
RHODE ISLAND STATE SNOWMOBILE CLUB
RHODE ISLAND WATERFOWLERS ASSOC INC
ROGER WILLIAMS STRIPER CLUB
RUMFORD HUNTING AND FISHING CLUB
SAYLES HILL ROD AND GUN CLUB
SMITHFIELD SPORTSMENS CLUB INC
SOUTH COUNTY ARCHERS
SOUTH COUNTY ROD AND GUN CLUB INC
STONY BROOK ROD AND GUN CLUB INC
THORNTON BEAGLE CLUB
VALLEY FALLS STRIPER CLUB
VICTORY SPORTSMENS CLUB INC
WALL [illegible] GUN CLUB
WARWICK SPORTSMENS CLUB INC
WINCHECK GUN CLUB INC
WOONSOCKET SPORTSMENS CLUB

November 5, 19[illegible]

U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Mass.

Dear Sirs:

The members of the Federated Rhode Island Sportsmen's Clubs would like to register their strong protest against the proposed flood control plan for the Pawtuxet River, as aired recently in a meeting at the Warwick City Hall, Warwick, R.I.

At that time, plans were proposed for the construction of a tunnel to channel flood waters out of the Pawtuxet and deposit them into Apponaug Cove of Greenwich Bay, thereby preventing flooding of homes which have been built in recent years on the floodplains of the Pawtuxet River in Warwick and Cranston.

Narragansett Bay and Greenwich Bay represent one of our most valuable natural resources. The shellfishing industry in Rhode Island provides employment and recreation to over 1200 licensed shellfishermen, as well as countless citizens who can take a limited amount without a license. Already, pollution closes large parts of the Bay permanently, and rain storms extend the pollution line periodically. With the tunnel pouring water into Apponaug Cove, the existing line of closure could at times extend to include all of Greenwich Bay. In addition, untold damage to the marine ecosystem could be caused by the addition of large quantities of fresh water, whether polluted or not.

We oppose the plan on this basis, as well as the feeling that people living off the floodplains should not be forced to give up their property to the tunnel. Let the houses on the flood plains be bought and removed, instead. Let's correct the problem where it occurs!

Sincerely,

Anne D. Holst

Anne D. Holst, Secretary

United States Department of the Interior
BUREAU OF OUTDOOR RECREATION
NORTHEAST REGIONAL OFFICE
Federal Building - Room 9310
600 ARCH STREET
Philadelphia, Pennsylvania 19106

IN REPLY REFER TO:
4120

NOV 5 1976

Mr. Joseph L. Ignazio
Chief, Planning Division
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

This responds to your request of September 29, 1976 for comments on the draft environmental statement for Pawtuxet River Watershed Study, Kent and Providence Counties, Rhode Island.

The statement would be improved if it mapped the recreational areas discussed in the text, especially their location with respect to proposed construction. The final statement should indicate whether any of the "smaller parklands" (par. 2.80) are public. If public, the statement should comment on any direct impacts upon these parklands.

Sincerely,

JAMES J. DONOGHUE
Assistant Regional Director

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

United States Department of the Interior

NATIONAL PARK SERVICE

NORTH ATLANTIC REGION
150 CAUSEWAY STREET
BOSTON, MA. 02114

IN REPLY REFER TO:
L-7619-NAR-(PE)
ER-76/965

November 9, 1976

Colonel John H. Mason
Division Engineer
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Mason:

Our Departmental Office of Environmental Project Review has asked that our comments on your draft environmental statement for Pawtuxet River Watershed Study (Kent and Providence Counties, Rhode Island) be sent directly to you. We understand that a Departmental commentary will be made later when requested by the Chief of Engineers.

We are pleased to note the consideration given in your draft environmental statement for the protection of cultural resources. The Corps' commitment to maintain coordination (page 4-4) with the Rhode Island Historic Preservation Commission is good and essential. Also essential is accomplishment of the underwater survey of Apponaug Harbor as relating to Area A and the Natick Diversion outlet works prior to completion of final design and start of construction.

The final environmental statement should contain the results of the underwater survey and recommendations therefrom and report further on coordination with the State Historic Preservation Officer (Rhode Island Historic Preservation Commission).

Sincerely yours,

Jack E. Stark

Jack E. Stark
Regional Director

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Post Office and Courthouse Building
BOSTON, MASSACHUSETTS 02109

[illegible] 1 1976

Division Engineer
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

Mr. Ignazio's letter of September 29, 1976, requested Departmental comments on the Draft Environmental Statement for the Pawtuxet River Watershed Study, Kent and Providence Counties, Rhode Island (ER-76/965). Our review is provided under authority of the National Environmental Policy Act (PL 91-190).

The primary emphasis of the Fish and Wildlife Service review is to determine the overall adequacy of the statement with respect to fish, wildlife, and related resources and the impacts of the proposed action on these resources and the utilization of such resources by hunters, fishermen, trappers, bird watchers, nature photographers, education groups, and others.

We offer the following comments.

General Comments

We consider information presented in the Environmental Impact Statement to be of a general nature with insufficient detail to predict and detect changes in environmental conditions or marine resources brought about as a result of the Natick Diversion. The statement lacks the depth and detail concerning environmental factors, as usually found in a standard 102 statement. The extent, value, use and relationship of ecological systems are not really discussed. The impacts of major alternative project proposals on these systems are also not addressed.

Additional attention is needed in comparing the project impacts (during the 100-year project life) on the resources expected to occur during the same period. The project impacts are often evaluated as though they affect only today's resources. This is an error because the resources, their value and use may, or may not, change before the project is even constructed!

CONSERVE AMERICA'S ENERGY

Save Energy and You Serve America!

Detailed Comments

1.00 Project Description

Page 1-3, para. 1.14 & 1.15 - This section should be clarified. As written it indicates that the sluice gates will be closed and the entire flow of the river will be diverted to Apponaug Cove unless flows exceed the diversion capacity.

We understand that only flow rates in excess of the maximum river capacity (approximately 2,000 cfs) are to be diverted to Apponaug Cove. Sufficient flows must be passed below the diversion intake during siphon operation in order to maintain existing wildlife and potential fish resources within the by-passed section of the river.

Page 1-3, para. 1.17 - This section indicates that if an anaerobic condition occurs inside the tunnel, pumps and portals could be provided for dewatering. The lack of discussion and detail concerning this problem indicates that a complete study of the potential for an anaerobic condition and its probable effect is warranted. The discharge of approximately 69,000,000 gallons of stagnant water retained within the tunnel with each diversion of flood flows could have a disastrous effect on living resources of Apponaug Cove and Greenwich Bay. We submit that if studies indicate that an anaerobic condition is likely, then pumps and portals must be provided and the tunnel pumped dry before an anaerobic condition is allowed to develop.

Page 1-4, para. 1.22 - Table I-1 summarizing project benefits is missing from our copy of the EIS.

2.00 Environmental Setting Without the Project

The environmental setting without the project should depict the resources as they are expected to be over the 100-year project life. Much of this discussion depicts the existing resource which will not be affected by the project.

This section of the report does not present definitive information on sport and commercial fisheries or their habitat in the Apponaug Cove-Greenwich Bay area. Therefore, an evaluation of the possible impact of the diversion on spawning activities, the use of the area as a nursery ground, and as a source of commercial and recreational harvest cannot be made. Detailed studies are required to provide information to allow a determination to be made.

Page 2-3, para. 2.16 - Figure II-1 does not portray an area of Class E water quality. The location of this area as indicated in the text should be portrayed in Figure II-1. Also it is unclear whether Figure II-1 represents the existing water quality of the lower Pawtuxet watershed or simply the standards set for 1975.

Page 2-4, para. 2.20 - If the Pawtuxet River exceeds state stream standards as indicated, what is the existing actual water quality classification in the area of the proposed diversion?

This section should be expanded to include and present all chemical and biological constituents and properties of the river at the diversion site.

Page 2-6, para. 2.34 - This paragraph should be expanded to include the following:

"With pollution reduction and adequate stream flow, the lower 11.2 miles of the Pawtuxet could support a warm-water fishery based upon largemouth bass, northern pike and chain pickerel. The potential of this fishery based on a population of 100 lbs. of fish/acre and a 40% harvest of one pound of fish per day, exceeds 5,400 man-days of fishing per year. With extensive access and a return of anadromous species, the lower river fishery could be expanded manyfold.

"There is a definite interest in restoration of the historic runs of anadromous fish to the Pawtuxet River. Major interest is in the restoration of alewives. Obstacles to restoration of alewives, shad and to a lesser extent smelt and possibly steelhead trout are dams, pollution, and low flows. With proper management, such as fishway construction, pollution abatement and streamflow regulation, anadromous fish could once again become a valuable natural resource for residents of this watershed and the state."

Page 2-7, para. 2.39 - Data and information from Southeastern Massachusetts University's Environmental Survey of Apponaug Cove and Greenwich Bay (page 4-?, para. 4.51) should be utilized to specify organisms which inhabit the various ecological communities.

Page 2-12, para. 2.74 - The discussion of the commercial shellfish industry is inadequate. As indicated, much of the desired information is unavailable. In order to accurately discuss the diversion's impact on the industry, a thorough study of hard and soft clam commercial harvest, effort, and potential for expansion in the area of the bay is necessary.

4.00 The Probable Impact of the Proposed Action on the Environment

The depicted probable impacts of the proposal are mostly derived by comparing the project (as though it is already in place) with today's resources. Consideration must be given to expected changes in the resource situation over the period of analysis. For example, stream pollution is expected to be abated in the future with a resulting improvement in the fishery resource. It is this improved resource that will be impacted by the diversion. The 100-year economic life of the diversion, measured from the date construction is completed, can also be assumed as a minimum physical life. Major changes in the resources, their value and use can be expected over this period. The proposed diversion, therefore, impacts the potential fishery resource, not the existing resource.

Page 4-1, para. 4.01 - This section forecasts the impact of sedimentation as minor due to the limited drainage basin and numerous small dams. We suggest that this section be re-evaluated in light of the periodic maintenance dredging which has and will occur every eight to ten years when approximately 45,000 cubic yards of sediment material requires removal from Pawtuxet Cove at the mouth of the Pawtuxet River.

Page 4-1, para. 4.03 - The diversion of flood flows would not have a significant effect on existing fish and wildlife resources of the river system. However, in the context of potential fisheries, the diversion of flood flows could upset a recovered river ecosystem.

With pollution reduction and restoration of fresh-water fisheries potential, diversion of flood flows could be detrimental to those species which may spawn in the lower reach of the Pawtuxet River. Proper water depth, water velocity and water quality must be maintained below the diversion during siphon operation in order to maintain the lower Pawtuxet River as a potential spawning area.

The Natick Diversion plan as proposed will present insurmountable obstacles to restoration of anadromous fisheries within the Pawtuxet watershed following pollution reduction. The overflow dam, spillway crest, and Natick Pond Dam will, in combination, prevent upstream migrations. Diverting water from the lower Pawtuxet during migration periods could affect the homing, spawning success, and juvenile development of anadromous species. Without the normal increased volumes of water discharged from the river during spring and autumn, adult and juvenile fish may not be stimulated to migrate at the proper time. If these seasonal peak flows (freshets) do not occur, fish may not migrate at all.

Effects on anadromous species will also be encountered at the withdrawal site. Should adults reach spawning sites, eggs and young fish moving downstream would be pulled into the opening of the intake with diverted flows. Mechanical damage will be incurred during passage through the tunnel. Upon discharge to Apponaug Cove, eggs and young fish would be subjected to sharp increases or decreases in temperatures, increased salinities, and rapid changes in pressure.

Page 4-4, para. 4.18 - This section indicates that there will be no impact on existing recreational resources. Page 4-2, para. 4.08, however, indicates that about eight acres (approximately three acres of streambed and five acres of the Pawtuxet River Reservation) of recreation and conservation land are to be converted to industrial use. Shortening the river in this area and converting conservation and recreation land to industrial use will result in loss of bird-watching, nature study, wildlife photography, and fishing opportunity.

Page 4-10, para. 4.53 - The low level of flooding analyzed by the computer is a rate of 200 cfs. Page 1-4, para. 1.18, however, indicates that the diversion rate in most years would be in the order of 300 to 800 cfs. In the final EIS we suggest this section present the data for 300 and 800 cfs diversion rates to more accurately reflect the expected annual event.

Page 4-10, para. 4.53 - It would be helpful if a table presenting chemical and biological constituents and properties of the river, Cove, and Bay were presented for the same periods or dates. This would be especially helpful since the water quality classifications range from C, SC, SB, to SA. (Also see comments on para. 4.58.)

Page 4-10, para. 4.58 - This section should be expanded to cover all water quality parameters. This seems especially appropriate because as indicated

on page 2-4, para. 2.20, pollutants associated with urban runoff will be carried into the river and diverted to the Cove and Bay. Recent EPA studies indicate that stormwater runoff in many cities is heavily laden with zinc and lead and that it probably contributes a greater pollution load than a city's treated waste outfalls. In some areas, the oxygen demand of urban stormwater runoff is three to five times greater than that of treated wastewater. Also, as indicated on page 2-4, para. 2.23, heavy metals are still present in sediment deposits of the river. During flood periods these sediments could be scoured and suspended in the diverted flood water. Heavy metals if diverted to the Cove and Bay could be assimilated by shellfish and finfish resources. Pesticides also could be diverted with flood flows and assimilated by fishery resources. As a result of physiological phenomena exhibited by marine organisms, elements contained in the diverted flood waters could be assimilated and concentrated in their structures. Estimates of biological accumulation relative to quantities of heavy metals and pesticides contained in river flood flows should be presented.

Page 4-11, para. 4.60 - We question the advisability of using a salinity reading of 10 ppt as the minimum point at which there will be some (adverse) effect to marine life. Depending on the duration of reduced salinities concentrations of 17.5 ppt have been shown to cause mortality among hard clams during or immediately after metamorphosis.

Additionally, detailed assessment of salinity tolerance of plants, invertebrates, and fishes are difficult because salinity effects proper may be increased, masked, or reduced by other simultaneously effective environmental factors such as light, temperature, water movement, dissolved gases, nutrition, and interaction between co-existing organisms.

More detailed information on tolerances to salinity variations, plus associated variables such as temperature, oxygen content, density and ionic composition, etc., are necessary before cause and effect relations can be assessed properly.

Page 4-12, para. 4.61 - If desirable to show the worst case condition the highest concentration encountered during the sample period should be projected. Also it would be helpful if data resulting from an actual flood event (flows in excess of 2,000 cfs) containing urban runoff could be analyzed and projected for all chemical and biological constituents.

Page 4-12, para. 4.63 - (See comments p. 4-10, para. 4.53)

Page 4-12, para. 4.64 - The data presented represent only those coliforms contributed by the diversion. In order to fully evaluate the diversion's impact on the Cove and Bay, cumulative data, i.e., that concentration resulting when all sources of coliform are considered, should be presented. Higher values than those depicted would likely occur.

5.00 Probable Adverse Environmental Impacts That Cannot be Avoided

Conclusions presented in these sections are judgments based on incomplete or short-term environmental surveys. While it is recognized that value judgments must be made on incomplete information, the report has suggested no alternative remedies available if future resource losses prove to be significant.

In order to prevent unnecessary destruction of fish, shellfish and wildlife habitat and provide enhancement opportunities for these resources, the following investigations will need to be undertaken.

1. A complete inventory of existing resources within the Cove and Bay which will be necessary in order to predict anticipated changes.
2. A determination of the suitability of the Pawtuxet for anadromous fisheries restoration in conjunction with pollution abatement.
3. A determination of the need for fish-passage facilities at barrier dams.
4. A determination of flow releases necessary to facilitate pollution abatement and fish passage in the lower Pawtuxet.
5. A determination of possible adverse effects on the fishery for anadromous species expected from diversion of water to Apponaug Cove.
6. A determination of the impacts a diversion program might have on a restored Pawtuxet fishery and the extent to which requirements of the fishery would limit diversion programs.
7. A determination of the effect on finfish and shellfish of salinity changes and associated variables caused by the diversion.
8. A determination of the effect on finfish and shellfish of silt redistribution and introduction caused by the diversion.
9. A determination of the effect on phytoplankton and zooplankton, especially ichthyoplankton, of temperature and salinity changes caused by the diversion.
10. A determination of the effect of the diversion upon the entrance, temporary residence, and egress of various species of young estuarine fish which depend on Apponaug Cove for a nursery.
11. A determination of effects on bottom organisms of changing conditions caused by the diversion.
12. A determination of the best means to alleviate the problem of stagnant water retained in the tunnel.

This section should contain the following information in addition to that presented:

Terrestrial Ecology

The major expected adverse terrestrial effects are those associated with the long-term loss of biological productivity through the removal of riparian habitat. Riparian habitat will be replaced by dikes and floodwalls and construction facilities. In all about 20 acres of the 30 acres to be cleared for construction of the local protection projects will be devoted to long-term non-biological use. The loss of riparian habitat will result in the demise of a segment of small mammal and invertebrate populations associated with this habitat. There is expected to be some loss of cover, breeding habitat, forage and home range area for birds and larger mammals.

If the slopes of the dike are seeded with wildlife food plantings and a 20-foot buffer is left between the base of the dikes and the river, this will provide habitat for native plants and animals.

Aquatic Ecology

Construction of the dikes, floodwalls and diversion are not expected to adversely affect existing fresh-water fishery resources. With pollution reduction and a restored fresh-water and anadromous fishery, the Warwick segment of the project with its channel relocation will result in a loss of 24,000 square feet of stream habitat and 1,200 feet of potential stream bank access.

Construction of the diversion will result in the permanent destruction of one-quarter acre of saltmarsh and bottom habitat in Apponaug Cove. In addition, the diversion may result in the permanent loss of, or greatly impair the potential for, anadromous fisheries restoration within the Pawtuxet watershed.

6.00 Alternatives to the Proposed Action

The discussion of alternatives is weak and appears to be based on economic, not environmental, considerations.

Page 6-2, para. 6.08 - The Environmental Quality (EQ) plan as outlined consists of Alternative D, the plan for dikes and floodwalls in the Warwick and Norwood areas. This alternative is designated as the EQ plan because it is the least environmentally damaging of the alternatives presented. Our understanding of an EQ plan is one which enhances by management, conservation, preservation, creation, restoration or improvement, the quality of certain natural and cultural resources and ecological systems in the area under study. We question whether Alternative D constitutes an EQ plan as envisioned by the Water Resources Council's Principles and Standards for Planning.

Page 6-16, para. 6.74 - A discussion of Alternative D should also evaluate the possibility of eliminating the channel relocation and providing dikes following the southern bank of the meander. This would eliminate conversion of publicly-owned conservation and recreation land to single-purpose use.

Page 6-18, para. 6.79 - Alternatives C-1 and C-2 do not appear to be the most environmentally sound approach to solving the flood problems in the lower watershed. A sound land treatment program accompanied by selective diking, floodproofing, floodplain zoning and flood insurance would essentially eliminate the threat to fish resources of the area and also water quality of Apponaug Cove and Greenwich Bay.

7.00 The Relationship Between Local Short-Term Uses of Man's Environment and the Maintenance and Enhancement of Long-Term Productivity

Page 7-1, para. 7.02 - This section concludes that the only pollution factor of significance will be the introduction of coliforms. We believe that a thorough analysis of additional pollutants contributed through urban runoff should receive equal consideration. Pollutants such as heavy metals, insecticides, and pesticides, and the biological oxygen demand of flood waters

should be similarly summarized. The effects of their introduction, assimilation and concentration by species within the Cove and Bay could have serious effects on the long-term productivity of fish and wildlife resources utilizing the area.

Page 7-1, para. 7.03 - Apponaug Cove is a nursery and spawning area for winter flounder. During larval development, modest changes in salinity may have lethal effects on fish larvae.

This section does not consider future uses and changing needs of society with respect to managing coastal zone areas. A discussion of whether the diversion is consistent with long-term objectives for coastal zone management is needed.

8.00 Irreversible and Irretrievable Commitments of Resources That Would Be Involved by Construction of The Considered Action

This section identifies only the depletable material resources consumed. Non-material resources, including a range of beneficial uses of the environment should be included.

Resources which may be irreversibly committed by construction and operation of the project are: (1) biological species destroyed in the vicinity, (2) water bodies to receive discharges to the extent that other beneficial uses are curtailed, and (3) land areas rendered unfit for other uses.

This section should also list the irreversible loss of 1/4 acre of saltmarsh and bottom habitat in Apponaug Cove due to construction of the diversion outfall. Approximately 24,000 square feet of stream habitat and 1,200 feet of stream bank will be permanently lost due to the channel excavation in the area of the Warwick Industrial Park.

A total of approximately 20 acres of riparian habitat will be cleared and occupied by the dikes and floodwalls.

Also, the loss of a biological resource is an irreversible commitment, in one sense, if remedial actions are not taken to correct such losses during the life of the project.

Summary Comments

We are concerned that the project and alternatives, as presented, afford no outstanding benefits to fish or wildlife. In general, adverse impacts appear to outweigh benefits. Adverse impacts resulting from the recommended project include:

(1) Permanent destruction of 1/4 acre of saltmarsh and bottom habitat in Apponaug Cove.

(2) Periodic pollution of Apponaug Cove and Greenwich Bay in association with siphon operation.

(3) Permanent loss of or greatly impaired potential for anadromous fisheries restoration within the Pawtuxet watershed.

(4) Permanent destruction of 24,000 square feet of stream habitat and loss of 1,200 feet of potential stream bank access.

(5) Loss of stream bank vegetation and associated wildlife displaced by dike and flood wall structures.

(6) Conversion of eight acres of publicly-owned recreation and conservation lands to single-purpose use.

In addition, there are many aspects which have potential for harm but have not been thoroughly evaluated or eliminated from concern by presentation of substantiating data. They are primarily associated with operation of the Natick Diversion and its potential effect on marine resources of Apponaug Cove and Greenwich Bay. Effects on marine resources not thoroughly assessed include:

(1) Salinity changes as influenced by associated variables caused by the diversion of fresh water to Apponaug Cove.

(2) Silt introduction and redistribution caused by the diversion.

(3) Temperature changes caused by the diversion.

(4) Possible changes in the value of Apponaug Cove as a nursery area.

(5) Changes in bottom conditions caused by the diversion.

(6) Pollution of marine waters caused by stagnant water retained in the tunnel and the effects its discharge will have on marine resources.

In summary, there are aspects of the Natick Diversion which need further in-depth study and have not been thoroughly evaluated. Further studies will be required to determine the effects of the diversion on fish resources of the area and also water quality of Apponaug Cove and Greenwich Bay. It is recommended that the project not be implemented but re-evaluated on the basis that a sound land treatment program, accompanied by a modified Warwick Local Protection Project and flood proofing, floodplain zoning, and flood insurance would appear to be a more environmentally sound project.

Sincerely yours,

ACTING Regional Director

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION I
J.F. KENNEDY FEDERAL BUILDING, BOSTON, MASSACHUSETTS 02203

November 12, 1976

Mr. Joseph Ignazio
Chief of Planning Division
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Mr. Ignazio:

We have reviewed the Draft Environmental Impact Statement for the Pawtuxet River Watershed Interim Report. Our comments are limited to the effects of the proposed Natick Diversion tunnel on the water quality and estuarine environment of Apponaug Cove and Greenwich Bay.

Although the EIS does discuss and analyze the effects of salinity changes on shellfish we feel that the uniform mixing or dispersion model used does not necessarily yield a projection of the maximum adverse effect. We feel that actual conditions would more correctly be represented by layered flow. Such flow would pose serious hazards to grazing larva, and thereby impede or completely eliminate replenishment of some species. A more detailed discussion of our position with regard to possible salinity damage is presented in the enclosed memo.

With regard to the discharge of coliform bacteria to Apponaug Cove the EIS states that the Pawtuxet River water quality should be greatly improved by the time the diversion is used. Although it is anticipated that sewage treatment plants to abate pollution in the Pawtuxet will be constructed by 1980, a solution to the problems created by urban run off and combined sewer overflows will most likely not be realized by that date. Both of these types of discharges are sources of coliform bacteria and would occur simultaneously with flood conditions and use of the diversion tunnel.

In addition, it is our opinion that the EIS does not sufficiently discuss the possible adverse effects of the discharge of storm water which has been confined in the

tunnel for up to a year. After that amount of time the waters would probably be devoid of oxygen, have a moderately high BOD and contain anerobic organisms which could be incompatible with the receiving water usage. The storage of storm water run off contaminated by combined sewer overflows and urban run off could be a potential source of disease. In our opinion, potential public health hazards of the inverted siphon should be investigated. It would appear that the only acceptable means of mitigating these possible impacts would be to keep the tunnel de-watered and provide for cleaning and debris removal after each flood. However, de-watering imposes other problems since it would require some protection or covering over the 200 foot deep hole to prevent people and animals from falling into it. We request that a more detailed analysis of impacts of stored storm water be made.

Our comments on this draft EIS have been classified as ER-2 in accordance with EPA's national rating system. Definitions of the categories are enclosed.

Thank you for the opportunity to comment on this draft EIS and we look forward to receiving the final. If you have any questions, please feel free to contact John Lynch of my office at 617-223-0400/0401.

Sincerely yours,

Wallace E. Stickney

Wallace E. Stickney, P.E.
Director, Environmental
Policy Coordination Office

Enclosure

EXPLANATION OF EPA RATING

Environmental Impact of the Action

LO -- Lack of Objections

EPA has no objections to the proposed action as described in the draft environmental impact statement; or suggests only minor changes in the proposed action.

ER -- Environmental Reservations

EPA has reservations concerning the environmental effects of certain aspects of the proposed action. EPA believes that further study of suggested alternatives or modifications is required and has asked the originating federal agency to reassess these aspects.

EU -- Environmentally Unsatisfactory

EPA believes that the proposed action is unsatisfactory because of its potentially harmful effect on the environment. Furthermore, the Agency believes that the potential safeguards which might be utilized may not adequately protect the environment from hazards arising from this action. The Agency recommends that alternatives to the action be analyzed further (including the possibility of no action at all).

Adequacy of the Impact Statement

Category 1 -- Adequate

The draft environmental impact statement sets forth the environmental impact of the proposed project or action as well as alternatives reasonably available to the project or action.

Category 2 -- Insufficient Information

EPA believes that the draft environmental impact statement does not contain sufficient information to assess fully, the environmental impact of the proposed project or action. However, from the information submitted, the Agency is able to make a preliminary determination of the impact on the environment. EPA has requested that the originator provide the information that was not included in the draft environmental impact statement.

Category 3 -- Inadequate

EPA believes that the draft environmental impact statement does not adequately assess the environmental impact of the proposed project or action, or that the statement inadequately analyzes reasonably available alternatives. The Agency has requested more information and analysis concerning the potential environmental hazards and has asked that substantial revision be made to the impact statement.

If a draft environmental impact statement is assigned a Category 3, no rating will be made of the project or action; since a basis does not generally exist on which to make such a determination.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DATE: October 28, 1976

SUBJECT: Pawtuxet River Flood Control Diversion Draft EIS

FROM: Clyde F. Shufelt, Chief CFS
Rhode Island - Connecticut Planning Branch

TO: Wallace E. Stickney, Director
Environmental and Economic Impact Office

We have reviewed the draft environmenta- impact statement and have formulated the following comments:

The dispersion model for the diversion water's effect on Apponaug Cove is based on an assumption which theoretically is incorrect. The model assumes one layer flow from the mouth of the outfall. This will not occur without the aid of mixing apparatus, which are not proposed. The Pawtuxet River water will form a fresh water wedge along the surface of the cove and a reverse saline wedge will be formed beneath it. Although the EIS indicates that the dispersion model represents a "worst case" condition, relative to bottom dwelling specials, it does not represent a "worst case" for certain lifeforms.

Apponaug Cove is an esturine structure which provides protection and nuturing for a large variety of both commercially and recreationally valuable marine life. As these species reproduce, many of their larvae forms become bouyant. A fresh water wedge such as the one originating from the diversion, lasting from a few hours to a few days could destroy a yearly spawn of grazing larva. Thus, very serious effects could result with respect to species replenishment.

Although the EIS correctly points out the shortcomings of the dispersion model and the almost total loss of a specie, should diversion and larvae stages occur simultaneously, the EIS does not treat this aspect as comprehensively as it does the assumed mixed condition.

The large percentage of hard shell clams present in the area are usually junvenile due to the heavy harvesting. The Rhode Island Health Department is considering a proposal to open the upper Bay for depuration shellfishing only. If this plan is adopted it would provide additional shellfishing opportunities in Narragansett Bay but could place a heavier shellfishing demand on the East Greenwich Bay area (from smaller fisherman), which would tend to deplete the area of the more adult stages. The net result is that the shellfish population of the area would be comprised of more juvenile forms, more susceptible to minor changes in the environment. They would also be more susceptible to suspended solids carried by the diverted water. The EIS, in most discussions, stresses only the adult life stages.

EPA Form 1320-6 (Rev. 3-76)

The waters in proximity to the discharge location are presently assigned a classification of SB or SC, and Greenwich Bay is assigned a Class SA designation. The lower classifications are due primarily to wastes originating from boats and individual outfalls. Ongoing abatement programs will result in improved water quality in the area and could result in higher assigned classifications.

Rhode Island water quality standards for Class SA and SB are predicated on complete removal of all waste sources (except cooling water) currently discharging to these waters. The standards also prohibit any new discharges to these waters. The EIS should, therefore, address the impact of the diverted Pawtuxet River water in maintaining the present standards as well as higher standards which will be achievable in the absence of the diversion.

EES 06-CE-44-19/7

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Science and Technology
Washington, D.C. 20230

November 19, 1976

Mr. Joseph L. Ignazio
Chief, Planning Division
Corps of Engineers
Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

The draft environmental impact statement (DEIS) entitled "Pawtuxet River Watershed Interim Report," which accompanied your letter of September 29, 1976, has been received by the Department of Commerce for review and comment.

The statement has been reviewed and the following comments are offered for your consideration.

General Comments

The subject DEIS does not accurately identify the probable impacts on aquatic resources that will result from the proposed Natick diversion. For example, it is assumed throughout the DEIS that losses to the biological community at the discharge site will be short-term and minimal. The minimal environmental impact assumption is based, in part, on the success of a computer model (see comments that refer to Page 4-12, para. 4.63 of the DEIS); and in addition, the assumption that industrial waste discharges will be discontinued.

These assumptions are not supported by reliable data or documented in the DEIS. The potential effects of marine resources not thoroughly assessed include salinity changes as influenced by associated variables (temperature, oxygen, rate of flow, etc.) caused by the diversion of fresh water of Apponaug Cove; the permanent destruction of 1/4 acre of saltmarsh and bottom habitat in Apponaug Cove; periodic pollution of Apponaug Cove and Greenwich Bay by the introduction of anaerobic water from within the tunnel and its effect on marine resources; possible changes in the value of Apponaug Cove as a nursery and spawning area for winter flounder; and the effect on marine resources of the introduction into Apponaug Cove and Greenwich Bay of trace quantities of heavy metals or

other treated industrial source pollutants (see comments that refer to page 2.4, para. 2.13 of the DEIS). These and other ecological considerations should be fully addressed in the final environmental impact statement.

Specific Comments

Summary Sheet, page i

3.(b) Adverse Environmental Effects -- This paragraph summarizes the adverse environmental impacts of the project. However, there is no mention of the potential adverse effects of the Pawtuxet River water quality on the marine life in Apponaug Cove and Greenwich Bay, other than the reduction in salinity.

1.00 Project Description

1.07 The Natick Diversion

1.15 Page 1-3, para. 1.14--It states that during a flood condition the sluice gates will close, cutting off the entire flow of the river and diverting normal plus flood waters via the tunnel to Apponaug Cove. According to page 4.9, para. 4.47, however, only river flows in excess of 2000cfs will be diverted to Apponaug Cove.

Page 1-3, para. 1.17 -- It is stated that if, necessary, pumps and portals could be placed in the outlet structure to eliminate anaerobic conditions within the tunnel during a non-flood period and to dewater the tunnel for inspection and maintenance. The discharge of approximately 69,000,000 gallons of stagnant water could have deleterious effects on living aquatic resources of Apponaug Cove and Greenwich Bay.

The feasibility of conducting studies to determine how soon water within the tunnel will become anaerobic could be discussed with the thought that perhaps water should be released prior to reaching anaerobic conditions.

1.22 Project Economics

Page 1-4, para. 1.22 -- Table I-1, referred to in this paragraph, is missing from the DEIS.

2.00 Environmental Setting Without the Project

Page 2-3, para. 2.16 - Surface Water Quality

It is stated that surface water quality in the Pawtuxet River Basin ranges from Class A to Class E as illustrated in Figure II-1. However, Figure II-1 does not indicate Class E conditions. Further, it is unclear as to the existing water quality. Does Figure II-1 represent water quality standards set in 1975, or the water quality condition in 1975? This should be clarified in the final statement.

In addition, locations referred to throughout Section 2.00, particularly with respect to water quality data, should be shown in better detail in Figure II-1. This paragraph refers to sludge deposits in several areas below the West Warwick Wastewater Treatment facility. These areas should be delineated in Figure II-1 and, in addition to sluggish flows and sedimentation resulting in these deposits, it should be pointed out that inadequately treated wastewater is a significant cause of sludge deposits in receiving waters.

Pages 2-3 to 2-4, paras. 2.18 - 2.21

These sections are unclear as to the existing water quality of the project area. On page 2-3, para. 2.18, it is stated that the dissolved oxygen content is improving and at the same time the coliform bacteria count has increased by approximately 4000%. Further in para. 2.20, it is stated that Pawtuxet River water continues to exceed state stream standards while in para. 2.21, water classification in Apponaug Cove ranges from SC to SB and in Greenwich Bay water quality is SA. It is conceivable that with a high dilution factor in Apponaug Cove and Greenwich Bay water quality can improve. However, to adequately assess water quality in the project area, this section should be expanded to include an analysis of all chemical and biological constituents affecting water quality, and a survey of the industries discharging into the Pawtuxet River to assess their potential effect on water quality in the future. Secondary treatment of industrial discharges is not sufficient in many cases to remove pollutants that affect marine life. In para. 2.20, the reference to Table II-3 should be II-2.

Page 2-4, para. 2.23 -- The first sentence of this paragraph states that industrial waste discharge is assumed to have been discontinued. This should not be assumed, but determined in fact whether or not industrial waste discharge has been discontinued. Water quality improvements under the 1972 legislation (Public Law 92-500) would not be due to a discontinuance of discharge, but by the upgrading of the treatment of these discharges. The upgraded treatment may or may not be sufficient to meet water quality requirements in Apponaug Cove and Greenwich Bay, even with dilution.

Page 2-5, paras. 2.25 and 2.27 -- Sludge storage at the two wastewater treatment facilities mentioned in these paragraphs could present a problem to water quality of the Pawtuxet River even during non-flood event periods. Surface runoff during and after rainfalls, and leachate from these areas, could contain pollutants which would degrade the water quality in the river.

Page 2-7, para. 2.39 -- This section should be expanded to provide an inventory of important marine resources within the Cove and Bay.

Page 2-8, para. 2.44 -- This section should include a discussion on the state of Rhode Island's interest in restoration of historic runs of anadromous fish to the Pawtuxet River. It may be possible that with proper management, such as fishway construction, pollution abatement, and streamflow regulation, anadromous fish could once again become a valuable natural resource.

Page 2-12, para. 2.74 -- In our opinion the importance of the shellfish industry warrants a more detailed discussion; particularly in regard to possible negative impacts upon that industry as a result of the proposed project.

4.00 The Probable Impacts of the Proposed Action on the Environment

Page 4-1, para. 401 -- This section forecasts the impact of sedimentation as minor due to the presence of dams upstream. However, maintenance dredging is required approximately every 8 to 10 years at Pawtuxet Cove.

Page 4-1, paragraph 403 -- It is stated that the diversion of flood flow would not upset the river ecosystem. However, the accumulated effects of diverting flow waters into Apponaug Cove should be investigated and presented in the final environmental impact statement. Further, the Natick Diversion will present many problems to anadromous fishes if the state decides to restore these resources within the Pawtuxet Watershed. The overflow dam, spillway crest, and Natick Pond Dam will prevent upstream migration. Diverting water from the low Pawtuxet during migration could effect homing and spawning success, and juvenile development of anadromous species. Further, should adults reach spawning sites, eggs and young fish moving downstream, during a flood condition, would be pulled into the intake structure with diverted flows. Mechanical damage will be incurred while passing through the tunnel. Upon discharge to Apponaug Cove, eggs and young fish would be subjected to sharp increases in temperature, increased salinities, and rapid changes in pressure.

Page 4-4, paragraph 4.18 -- It is stated that the proposed flood control measures will have little or no impact on existing recreational resources within the project area. Page 4-2, paragraph 4.08, indicates about 8 acres would be created by straightening of the Pawtuxet River course with subsequent land fill. It is our understanding that approximately 3 acres consist of str[illegible] and 5 acres consist of Pawtuxet River Reservation. Therefore, shortening the river in this area will eliminate 8 acres of recreation land for industrial use. This we consider to be a major environmental impact, and believe it should be so defined in the final environmental impact statement.

Page 4-10, paragraph 4.58 -- This paragraph should be expanded to cover all water quality parameters. On page 2-4, paragraph 2.20, it is noted that pollutants associated with urban runoffs will be carried into the river and diverted to the Cove and Bay. Recent Environmental Protection Agency studies indicate that stormwater runoff in many cities consist of heavy metals and contribute a greater pollution bad than does a treated waste outfall. Also, on page 2-4, paragraph 2.23, it is noted that heavy metals are still present in sediment deposits of the river. During flood periods these sediments could be diverted

to Apponaug Cove and Greenwich Bay; thus the possibility exists that heavy metals could be assimilated by shellfish and finfish resources. Therefore, biological accumulation of heavy metals contained in river flows should be expected in Apponaug Cove and Greenwich Bay.

Page 4-11, paragraph 4.60 -- It is stated that a salinity reading of 10 ppt is considered to be a point at which there will be some effect to marine life. Such a statement should be qualified and substantiated in the final environmental impact statement. Further, we question such a statement because detailed assessment of salinity tolerance of aquatic resources should be analyzed in conjunction with other environmental factors such as light intensity, temperature, water movement, dissolved gases and nutrients. Before such a determination can be made, more detailed information on salinity variations and associated variables is needed to accurately assess the computer model.

Page 4-12, paragraph 4.63 -- Page 104, paragraph 1.13 indicates that the diversion rate in most years would be in the order of 300 to 800 cfs. However, in this section 200 cfs (an annual event) was used as the diversion rate for the computer. This section should present data for 300 and 800 cfs diversion rates to more accurately assess the expected annual event.

5.00 Probable Adverse Environmental Impacts that Cannot be Avoided

The adverse environmental impacts presented in this section are non-specific and based on incomplete or outdated environmental surveys. For instance, on Page 5-1, paragraph 5.04 there is no mention that construction of the diversion will result in permanent destruction of 1/4 acre of saltmarsh and bottom habitat in Apponaug Cove. In addition, the Warwick segment of the project with its channel relocation will result in a loss of stream habitat. Further, the diversion may greatly impair the potential for anadromous fisheries restoration within the Pawtuxet

Watershed.

6.00 Alternatives to the Proposed Action

Page 6-18, paragraph 6.79 -- There are many unanswered environmental concerns surrounding alternatives C-1 and C-2 that have not been thoroughly evaluated. Further investigation should be undertaken to determine the effects of the diversion on fishery resources and water quality of Apponaug Cove and Greenwich Bay.

7.00 The Relationship Between Local Short-Term Uses of Man's Environment and the Maintenance and Enhancement of Long-Term Productivity.

Page 7-1, paragraph 7.02 -- This paragraph concludes that the only pollutant of significance introduced into Apponaug Cove will be coliform. However, it is certain that heavy metals, insecticides, pesticides and BOD of flood water could seriously affect the long-term productivity of fishery resources of the project area.

Page 7-1, paragraph 7.03 -- Apponaug Cove is a nursery and spawning area for winter flounder. During larval development, modest changes in salinity may have detrimental effects on these species, and on certain invertebrates as well.

8.00 Irreversible and Irretrievable Commitments of Resources that Would be Involved by Construction of the Considered Action

This section should identify resources which will be irreversibly committed by construction and operation of the project, these are: the irreversible loss of 1/4 acre of saltmarsh and bottom habitat in Apponaug Cove and loss of stream habitat due to channel excavation in the Warwick Industrial Park area.

9.00 Coordination

According to the Coastal Zone Management Act of 1972, all Federal projects affecting the Coastal Zone must be consistent with that state's approval Coastal Zone Management Program. We

realize that Rhode Island does not have an approved CZM plan but it is advisable that a project of this magnitude be coordinated with the Coastal Resources Management Council of Rhode Island.

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving eight copies of the final statement.

Sincerely,

Sidney R. Galler

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

AREA OFFICE
15 NEW CHARDON STREET
BOSTON, MASSACHUSETTS 02114

AREA OFFICES
Boston, Massach
Hart , Conne
Ma

REGION I
REGIONAL OFFICE
BOSTON, MASSACHUSETTS

November 22, 1976

IN REPLY REFER TO:
1.1SS

U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

Attn: Mr. Joseph L. Ignazio
Chief, Planning Division

Subject: Pawtuxet River Watershed Study
Rhode Island

Dear Sir:

The Boston Area Office has reviewed the above Draft Environmental Impact Statement within its area of expertise.

We have no comment to make regarding the proposal to control flooding of low land areas of the Pawtuxet River Watershed Area.

Thank you for giving this agency an opportunity to review and comment on the above proposal.

Sincerely,

Acting Area Director

MEMORANDUM

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
FOOD AND DRUG ADMINISTRATION

TO: U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02154

DATE: December 6, 1976

FROM: Chief, Northeast Technical Services Unit
Shellfish Branch, FDA

SUBJECT: Review of Draft - Environmental Impact Statement
Pawtuxet River Watershed - Interim Report

We have reviewed the subject report and have the following comments:

1. The Natick Diversion Tunnel is completely against the philosophy of the National Shellfish Sanitation Program regarding public health protection and we categorically oppose it. The reason is that the tunnel is diverting a major flow of highly polluted (industrial and domestic) water to the relatively small Greenwich Bay which contains a significant clam resource. From the information in the report, we can calculate that it would amount to a bacterial equivalent of the raw sewage of over 2,000 people. We thus prefer the flood control alternative of walls and dikes.

2. The entire Greenwich Bay would have to be reclassified from class SA waters to <u>conditionally approved</u>. With the anticipated diversions of 300-800 CFS and coliforms of 13,000/100 ml or more, the waters will not meet the approved area of 70/100 ml according to the information provided. If diversions last one or two days and the detention time in the Greenwich Bay is one to two days and three days are allowed for shellfish to purify (bacterially only) themselves, the total closure time to shellfishing will most likely be at least 7 days for each single event. If the state decides against managing Greenwich Bay as a <u>conditionally approved</u> area, then according to the National Program the entire Bay would have to be permanently closed to direct marketing.

3. We do not believe that the 13,000 coliforms per 100 ml is a realistic value for such a highly polluted and variable river. We do not believe that the 13 bacteriological samples collected are statistically significant in such an important and costly project. Furthermore, the 13,000 value represents a geometric <u>average</u> and not extreme values which generally occur with high runoff and high river flows. Although the hydrographic part of the report is without question, the sanitation portion is lacking with regard to evaluation of public health significance. For example, there is no guarantee that water quality in the Pawtuxet River will improve by mid 1980's as was suggested in the report. Population growth could easily offset any water pollution control improvements in that time. Also, Figure IV-4 shows about one quarter of the Bay to have 2% of the value of the Pawtuxet River water - in other words a coliform of 2% X 13,000 = 260/100 ml.

This is predicted for a flow of 200 CFS. Why were figures not presented in the report for the typical expected diversions in the usage of 400-800 CFS? Furthermore, the shellfish standard is 70/100 ml. Therefore we are looking for what portion of the Bay exceeds 0.54% of the Pawtuxet River at up to 800 CFS. It appears then that the entire Bay will exceed the shellfish standard under typical diversions.

4. From the public health point of view, the industrial wastes were not even considered in the report. Mollusks concentrate organic and inorganic wastes and do not purge themselves for months. Thus, there is the possibility of permanent closure because of high concentration of heavy metals, PCB's, hydrocarbons, etc. not removed in typical sewage treatment plants. In summary, then, we recommend a complete reevaluation of the public health aspects of the Environmental Impact Statement regarding harvesting of clams or other species of mollusks.

James L. Verber
Chief, NE Technical Services Unit

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

HISTORICAL PRESERVATION COMMISSION
Old State House
150 Benefit Street
Providence, R. I. 02903
(401) 277-2678

December 10, 1976

Mr. Joseph L. Ignazio
Chief, Planning Division
New England Division, Corps of Engineers
U. S. Department of the Army
424 Trapelo Road
Waltham, MA 02154

Dear Mr. Ignazio:

This office has reviewed the "Draft Environmental Impact Statement, Pawtuxet River Watershed" and has the following comments:

1. Previous correspondence from this office (may 10, 1976, June 28, 1976) has indicated the need for an archeological survey. Currently this study is in the process of being completed by Richard Anuskiewicz and Dr. Frederick Warner with the help of our office.
2. Because the environmental impact statement will be incomplete without the cultural resources information, this office will reserve its opportunity to comment until the appropriate material is received and reviewed.

Sincerely yours,

Frederick C. Williamson

Frederick C. Williamson
State Historic Preservation Officer

FCW/afc

SUMMARY OF MAY 1977 PUBLIC MEETINGS

On 19 May 1977, a hearing was held in Warwick, Rhode Island to obtain public comment regarding revised flood control alternatives on the lower Pawtuxet River Watershed. Approximately 50 people attended.

At this time, three alternatives were presented. They consisted of a No-action plan, designated as Plan F the Natick Diversion-Warwick Local Protection; referenced as Plan C-1, and a revised Warwick Local Protection project in conjunction with additional flood control storage at Big River Reservoir. This was designated as Plan D. The primary element in the No-action plan is participation in the National Flood Insurance Program along with regulatory measures and a sound land use program. The revised Warwick Local Protection project had an identical alignment as the one presented with the Diversion except that its height would average three to five feet higher. This compromising Plan is not as effective as the Natick Diversion with the Warwick Local Protection Works; protecting only 489 ownerships, leaving 284 unprotected. The NED staff also presented the environmental aspects of each Plan.

In the public comment portion of the meeting, Plan D, the revised Warwick Local Protection project, received positive response. The reason was that the alternative eliminated the Natick Diversion which was objected to very strongly at the October 1976 meeting on the grounds of its cost as well as certain environmental considerations such as the affect on Apponaug Cove.

A statement was given on behalf of J. Friedemann from District 35 of the State legislature. He reiterated a strong opposition to the diversion as the cost connected with it is prohibitive.

Gloria Kennedy Fleck, Senator from the Rhode Island State Legislature supported the compromise plan in that it would be a working alternative to the flooding problem. She urged the Corps to continue listening to the comments of those in the affected areas.

Representative Maureen Maigret found the proposal acceptable because it eliminated the Natick Diversion which she strongly opposed at the previous meeting. She stated that the people in her district would also find it acceptable.

William Lovely, representative from District 30, supported Plan D as a means of protection. He said that Big River Resevoir would benefit not only the residents of Warwick, but the entire State.

The West Greenwich Town Council President gave support to the implementation of Plan D as long as its development does not require

further acquisition of non-State owned land. If this were the case then they definitely would oppose it. The NED staff responded that at its present design state the additional height of the dam would not require anymore land for flood storage which is not already owned by the State.

A member of the Water Resources Board of Cranston was very much interested in the development of Big River. He foresaw problems, financially, legislatively, and legally, however, pledged their support for the project.

The Providence City Planner, representing Mayor Vincent A. Cianci, acknowledged that most of the measures that can be taken within the South Branch Watershed to ameliorate the Pawtuxet River flood problem are now properly included in Plan D thus supporting the Local Protection Project and Big River Reservoir. He did state that there was room for further consideration of other measures which he felt could effectively lower main stem flood damages. Such measures could include removal of obstructions and restoration of the river's natural gradient. He recommended that the Corps explore these possibilities for cost effectiveness. The NED staff responded that these additional measures had been looked into by the Hydrology Department. Channel improvements, such as those mentioned, would not have a significant effect on reducing flood flows due to the flat gradient of the river bed. It was also stated that it was within the Division Engineers' authority in making any recommendations concerning the study, to address a proposal under which the Corps would construct the Big River Reservoir. The city might desire to be the sponsor of such a proposal. This, then, could result in the Corps undertaking the project.

The city planning Director for Cranston was in favor of the Big River Reservoir project and abandoning of the diversionary tunnel. However, realizing that the flood storage capacity of the flood plain is continually being reduced by development, opposed the construction of dikes. He stated that tax money should not be used to protect the investment of commercial and industrial establishments when they knowingly built in the low lying areas because the land was cheaper. In addition, his experience has been that industry and commerce will tend to protect themselves anyway in case the dike or gates fail to operate. Therefore, it should be recommended that restrictions on the present and future flood plain should be implemented.

The NED staff made one observation regarding these comments. It was stated that the Corps was not the Federal agency which can implement the Flood Insurance Program or all of the obligations that go with it. This is actually done by HUD. The Corps does have under its

authority what is known as Section 73 to look at non-structural solutions. Also, these options were emphasized in the No-action program which meant No-action on the part of the Corps but did not mean No-action on the part of the communities. It was pointed out, by another individual, that the burden for preventing future flood losses is clearly on the local community. If they do the job, the mistakes made in the past will not continue.

Other individuals also pointed out the need for a plan of regulatory measures which would restrict development in the flood plain.

The Mayor of the city of Warwick, Joseph Walsh, expressed his pleasure with Plan D which was presented. His only concern with the plan was that it required the city to contribute for the cost of land acquisition and maintenance. This would average about $100,000 per year for 20 years. The reason for this being that the Local Protection Project requires local financing whereas the Natick Diversion is a totally Federal project. He disagreed with this philosophy because the cause of the Warwick flooding problems were regional in nature, that being the upstream development in other communities. Since there would be about five years until construction would begin, the city would have the opportunity to enter into any agreement with the Corps and request that these financial arrangements be changed. Until then, he will search for the necessary funding recognizing the regional nature of the project. The city will also coordinate with the Governor and the Pawtuxet River Authority in an attempt to find a solution to the financial burden.

CORRESPONDENCE FROM 1977 PUBLIC MEETING

State of Rhode Island and Providence Plantations

REPRESENTATIVE
ZYGMUNT J. FRIEDEMANN
335 George Arden Avenue
Warwick, Rhode Island 02886

Room 326 State House
Providence, Rhode Island 02903

Committee on Judiciary

House of Representatives

STATEMENT ON PAWTUXET RIVER WATERSHED
MADE BY MR. CHUCK HAHN ON BEHALF OF
REP. Z. J. FRIEDEMANN, DIST. 35 WARWICK
AT PUBLIC HEARING, MAY 19,1977

As I have testified at the public hearing on October 14, 1976, I wish to reiterate tonight on behalf of my constituents in the 35th District again my strongest possible opposition to the proposed Natick Diversion combined with the Local Protection Project outlined under Plan C-1 on the agenda.

My opposition tonight is based upon the same reasons submitted in the October testimony:

(1) An absence of any meaningful public support for the project which calls for approximately $60 million expenditure of public money, and a total objection to the Diversion Project by the people of District 35.

(2) The financial inability for the City of Warwick to cope with nearly $100,000 annually over 20 years span of time.

It has to be noted again that while the cost of the Diversion project was prohibitive to the City of Warwick in October 1976, it is even more prohibitive now in the light of fiscal problems the City experiences combined with increased burden of property tax.

In as much as Plan D does not affect adversely my constituents, I take no issue on it, although the cost connected with it (being identical as under Plan C-1) is prohibitive.

In summary, the U.S. Corps Engineers has to learn to accept the local decision made in October 1976 that the Diversion Project is absolutely, positively, and categorically negated, and that therefore there is no need to keep reviving it.

Respectfully submitted,

Zygmunt J Friedemann

Zygmunt J Friedemann
Representative, District 35

Executive Chamber, City of Prov[illegible]dence, Rhode Island

Vincent A. Cianci, Jr.
MAYOR

M[illegible] 19, 1977

Col. John P. Chandler, Division Engineer
New England Division, Corps of Engineers
Department of the Army
424 Trapelo Road
Waltham, MA 02154

Re: Pawtuxet River Watershed Flood Management Study

Dear Col. Chandler:

This statement is in response to the announcement of April 1[illegible], 1977 of the public meeting on alternative plans for flood management in [illegible] Pawtuxet River Watershed.

The City of Providence bears heavy responsibility for flowage in this river basin. Our metropolitan water supply system presently controls 92.8 square miles of the river's total basin area of 229.6 square miles above the Scituate Reservoir dam; and an additional 29.7 square miles above the proposed Big River Dam are planned to become part of the same water supply system. About 4.6 square miles of the tributary Mashapaug Brook watershed are also controlled by dams owned by the City of Providence; and the Broad Street dam also under City of Providence responsibility substantially affects the streambed characteristics of the lower main stem of the Pawtuxet River. In any plans for reducing flood damages in the adjoining flood plains, therefore, the City of Providence should and can be an important cooperator and collaborator in both the design and operation phases. Hence, our active interest is continuous throughout these proceedings.

Ever since the public meeting of October 14, 1976, the City of Providence has in conference and correspondence with the Army Corps of Engineers urged the Corps to restudy the opportunities for reducing flood dangers in the lower Pawtuxet flood plain. We were encouraged by the attentive courtesy shown in February and May to my representatives in two technical conferences at the Corps' headquarters, and by the invitation to discuss a new comparison of alternatives at an April conference at the Statewide Planning Program office.

In the notice issued for this public meeting, we observe that construction of Big River Reservoir including an additional height of 2½ feet to be assigned for flood storage has been moved from the category of "future actions" to active status within Plan D. Also, in publicity released April 25th by the

Col. John P. Chandler, Division Engineer
Page 2
May 19, 1977

Rhode Island Water Resources Board, it appeared possible that the Army Corps would propose to fund construction of the entire reservoir and dam, with repayment of the water supply portion to be made over 50-years from water revenues. In view of the economic benefits to Metropolitan Providence and the State of Rhode Island, we would probably favor such a proposal but must await its presentation before we can study it and comment further concerning it.

The City acknowledges that most of the measures that can be taken within the South Branch watershed to ameliorate the Pawtuxet River flood problem are now properly included in Plan D. However, this leaves for further consideration those other measures which we feel could be effectively taken in the river's lower main stem to further reduce flooding damages, including removal of obstructions and restoration of the river's natural gradient and velocity. The City recommends again that the Corps should explore these for cost effectiveness.

Sincerely,

Vincent A. Cianci, Jr.

VINCENT A. CIANCI, JR.
Mayor of Providence

VAC

cc: Governor Garrahy
Senator Pell
Senator Chafee
Representative St. Germain
Representative Beard
John A. Doherty, Chairman, Water Supply Bd.

Mayor James L. Taft, Jr. Executive Chamber/City Hall/Cranston, Rhode Island 02910

June 30, 1977

Colonel John P. Chandler
Army Corps of Engineers
Department of the Army
424 Trapelo Road
Waltham, Massachusetts

Dear Colonel Chandler: RE: Pawtuxet River Flood Control

I am pleased that the Army Corps of Engineers no longer recommends the earlier alternative of a diversionary tunnel. If the choice must be limited to the remaining alternatives, the combination of Warwick Local Protection with the Big River Reservoir is preferred.

I concur with the feeling of the citizens of Warwick that they should not be required to pay one million dollars toward the cost of the local protection. The entire project should be federally funded.

The "probability" that the federal government may pay for the additional cost of the flood control element to Big River Reservoir should be made more definite and not require it to be abandoned or to be financed by the state.

It should be noted that the "most optomistic" schedule for actual construction to begin is five years and a realistic estimate for completion of both elements could easily be ten years or more. In the meantime, the residents in Warwick who are the most endangered are the least able to take measures to protect themselves.

I realize that while the Army Corps of Engineers has communicated with other federal departments, its assignment tended to limit the solutions essentially to expensive and time consuming engineering projects.

The Corps of Engineers should be authorized to continue without delay with plans for the recommended Warwick Local Protection and Big River Reservoir.

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In the meantime, I would suggest that a study be made jointly by the Army, the Federal Insurance Administration, and the Environmental Protection Agency. This could very well result in a solution that would be of more immediate benefit, less costly, and less damaging to the environment, and stressing prevention of floods rather than cure.

Sincerely yours,

James L. Taft, Jr.
Mayor

JLT:km
cc:Senator John H. Chafee
Representative Edward P. Beard
Governor J. Joseph Garrahy
Mayor Joseph Walsh

May 23, 1977

Colonel John P. Chandler
Corp of Army Engineers
424 Trapelo Road
Waltham, Mass., 02154

Attention of: NEDPL-L

Dear Colonel Chandler:

We, the residents of the Belmont Park section of Warwick, R. I., do hereby voice our approval of Plan D for Warwick Local Protection, Big River Reservoir and Future Measures, and we urge the Corps of Army Engineers to proceed with speedy implimentation of this project in order to protect the residents and property of our neighborhood from future flooding of the Pawtuxet River.

John [illegible] 123 Summer Ave [illegible]
Barbara L. DellaPorta 34 Summer Ave Warwick, R.I.
[illegible] 30 Summer Ave Warwick R.I.
[illegible] Schmitt 45 Summer Warwick R.I.
Anthony Cole 14 Wingate Ave Warwick R.I.
Laurie [illegible] 14 Wingate Ave, Warwick R.I.
Helen Burke 41 Summer Ave
[illegible] 27 Kingston Ave Warwick, R.I.
James B. Butler [illegible] Kings Ave Warwick R.I.
[illegible] Ave Warwick R.I.
Irene [illegible] 46 Kingston Ave [illegible]
[illegible] Kingston Warwick R.I.
Richard A. DellaPorta 34 Summer Ave Warwick R.I.
[illegible] Warwick R.I.
Marguerite Johnston 77 Kingston Ave
[illegible] Johnston
[illegible] Johnston
[illegible] 33 First Ave - Warwick R.I.
Barbara [illegible] 33 First Ave - Warwick R.I.

Elizabeth G. Fleming 115 King Ave Warwick R.I.
Arnold G. Fleming 115 King Ave Warwick R.I.
Richard Della Porta 34 Sumner Ave Warwick R.I.
Betty Pierce Sumner Ave. Warwick
Michael E. Pierce 193 Sumner Ave Wwk
Edna Johnston 109 King Ave Warwick
Mr. [illegible] 84 Sumner Ave Warwick R.I.
Anna C. Colucci 84 Sumner Ave Warwick R.I.
George & Catherine Contemarko 58 Wingate Ave Warwick R.I.
Burton H. Dawson 62 Wingate Ave. Warwick R.I.
Mr & Mrs John Parker 65 Wingate Ave Warwick R.I.
Mary Jacobs 5 Wingate Ave War. RI
Alice P. & F. Souza Jr. 45 Heath Ave Warwick R.I.
Maria H. [illegible] 45 Heath Ave Warwick R.I.
Seymour R. J. Lapied 45 Heath Ave. Warwick, R.I.
Arthur F. Whalen 55 Heath Ave. Warwick R.I.
Alice J. Whalen 55 Heath Ave. Warwick R.I.
Joseph Ruggieri 60 Heath Ave. Warwick R.I.
Glen J. Golden 18 Wingate Ave. Warwick R.I.
Louise B. Golden " " " "
Linda Zuercher 59 First Ave. Warwick R.I.
Albert L. Zuercher 59 First Ave War R.I.

State of Rhode Island and Providence Plantations
EXECUTIVE CHAMBER, PROVIDENCE

J. Joseph Garrahy
Governor

August 15, 1977

Colonel John P. Chandler
Division Engineer
New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Attention: NEDPL-L

Dear Colonel Chandler:

Following the public meeting which you held on the Pawtuxet River flooding problem in Warwick, Rhode Island, on May 19, 1977, we have carefully considered the alternatives presented and their ramifications for Rhode Island and the people and communities most directly concerned. I am pleased to endorse "Plan D" involving Warwick local protection, the Big River Reservoir, and future measures as it was presented at the public meeting and as described in the Corps of Engineers' reports on the Pawtuxet River Watershed.

Substantial support for "Plan D" was demonstrated at the public meeting by local governments, members of the General Assembly, and the public. I recognize that three issues require further exploration:

1) Utilization of the proposed Big River Reservoir for both water supply and flood storage purposes, and possible Corps of Engineers construction of or financial participation in this project: These arrangements appear to offer distinct advantages to Rhode Island in constructing an essential facility. While all aspects of such a cooperative venture must be worked out in detail before a firm decision to proceed to construction can be made, I believe that we should pursue the necessary studies and negotiations immediately. The Rhode Island Water Resources Board will contact you directly on this matter.

Colonel John P. Chandler
Page 2
August 15, 1977

2) CIBA/Geigy Company wetland permit: This firm currently holds a State of Rhode Island wetlands permit. This permit requires that certain areas be left undeveloped in order to accommodate storage of flood waters. The flood protection which would be provided by "Plan D" may make the continued retention of all or part of this area unnecessary. I am directing the Rhode Island Department of Natural Resources to review this matter.

3) Non-federal share of project cost: The required non-federal contribution may present a problem to the City of Warwick, even though it will not be needed for perhaps five years. One method by which this burden may be lessened is through the acquisition of property through donation as a means of meeting part of the non-federal share. This, of course, is unclear at this time and will require substantial investigation in the months ahead.

I want to extend my appreciation to you and your staff for your efforts in studying and presenting alternatives to the plan that you had initially selected. I believe that the compromise solution which "Plan D" represents is a valid trade-off between cost, degree of flood protection, environmental impact, and other factors which could not have been achieved without the cooperation of all concerned.

Sincerely,

J. Joseph Garrahy
J. Joseph Garrahy
GOVERNOR

3 March 1979 Workshop Meeting

On 3 March 1979, a workshop meeting was held at the Aldrich Junior High School in Warwick, Rhode Island. The meeting was arranged by local interests. The purpose was to formally announce our plans for the Norwood-Belmont area -- the land bank or acquisition program for 32 homes north of First Avenue. Between 75 and 100 local residents along with Representative Beard, congressional aids from Senators Chaffee and Pell's offices, Mayor Walsh, Barbara Sokoloff, the City Planner, Anne Stubbs from the Governor's Office, and an official from the State Transportation Office were in attendance.

The meeting was initiated with a history of the study and then the acquisition program was explained. At this time only the 32 homes north of First Avenue were considered in the acquisition program due to the uncertainty of the programs acceptance by local interests. Many of the homeowners south of First Avenue objected to this scheme as their flood problems are as severe as those homes north of First. Virtually all of the homeowners included in the original acquisition program accepted the proposal. We were led to believe by Warwick officials that the plan would not be generally acceptable to locals. For this reason the acquisition was limited to a minimal number of homes. About 8 to 18 homes south of First Avenue would have been included in the acquisition program originally due to their first floor elevations being below the 100-year flood as modified by Big River and under natural conditions respectively. As a result of this meeting and subsequent local meetings with residents of Norwood (Belmont) a high degree of public acceptance is evident. The current plan calling for acquisition of 40 to 50 homes depending upon conditions was advocated.

Also at this meeting Mayor Walsh formally announced that he was not supportive of the Warwick Avenue Local Protection due to the required cost sharing formula.

CORRESPONDENCE FROM 1979 MEETING

Betty Pierce
193 SUMNER AVENUE
WARWICK, R.I. 02888

February 4th, 1979

Congressman Edward P. Beard
307 Federal Building
Providence, Rhode Island

Dear Congressman:

First of all, I would like to thank you for the very nice letter of sympathy received from you regarding the death of my Mother-in-law, Nora Pierce. She thought quite highly of your Mother, and it was so kind of you to think of us at this time. I thank you in behalf of the entire Pierce family.

Secondly, I am writing in behalf of the residents of BELMONT PARK, the low-lying area of Norwood, bordered by the Pawtuxet River.

We have fought for the past ten years for permanent flood protection for our homes. We even fought for flood protection all along the Pawtuxet River (the Natick diversion) for all of Warwick. All that has been accomplished in all this time, were Temporary dikes put in by the Army Corps of Engineers in 1970.

Well, last week, on January 26th, our temporary dikes were washed away by the angry waters of this river. Our homes were contaminated by sewerage and oil, our boilers and belongings damaged, and the residents evacuated for days.

The worse of this whole frustrating situation being the loss of three lives which were flood-related.

Joe Walsh has helped us so very much in the past ten years, fighting with us every step of the way, even to filling sand-bags with us. Last Sunday, he spent the entire day with us, and Gerry Gibbons, our councilman, was with us since Thursday night. They have helped us in every way, but there is just so much the City of Warwick can do.

Now everyone knows that you are a fighter, so I am asking for your help. We sure could use a friend in Congress.

If you could possibly come and meet with us, we would certainly appreciate it. Perhaps we could fill you in with more details of this terrible situation and our ten year battle.

As things stand now, without our temporary dikes, we are back to where we were in 1969.

Thank you so very much.

Yours truly,

Betty Pierce

EDWARD P. BEARD
2D DISTRICT, RHODE ISLAND

WASHINGTON OFFICE:
151 CANNON HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-2735

COMMITTEES:
EDUCATION AND LABOR
VETERANS' AFFAIRS
SELECT COMMITTEE ON AGING

Congress of the United States
House of Representatives
Washington, D.C. 20515

DISTRICT OFFICES
307 POST OFFICE ANNEX
PROVIDENCE, RHODE ISLAND 02903
(401) 528-4861

325 WEST SHORE ROAD
WARWICK, RHODE ISLAND 02889
(401) 528-4871

Providence, R. I.
February 12, 1979

Colonel John P. Chandler
New England Division, Army Corps
of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Chandler:

As you know, there is a meeting schedule for March 3, 1979 at 9:30 A.M. with representatives of the Army Corps of Engineers and the residents and governmental representatives of the City of Warwick concerning the serious flood problem confronting the people of the Belmont area of that City.

For approximately forty years, the situation in this flood plain has become progressively worse. In 1968, for example, the people of the area were hit with a flood which had the severity of a "15 year" flood. The most recent one is estimated to be of the "25 year" variety. In this last instance, two deaths have been indirectly linked to it.

For over ten years, the people of the Belmont area have been promised protection. In 1970, dikes along the Pawtuxet River were supposed to be the answer to the problem. In 1972, protection was going to be provided by the so-called Pontiac Diversion. In 1976, this was superseded by the Natick Diversion plan. All that seems to be happening is that we are being diverted from achieving the goal of providing the people of the area with the protection they need.

The residents have been more than patient with the slowly moving wheels of government. They are becoming more frustrated with each passing day. Furthermore, as a result of the progressive nature of the flooding, residents are not only fearful

Colonel John P. Chandler
Page 2
February 12, 1979

of loss of property, but of their lives as well. Most of the families still have a desire to remain in the area. Some of them have been there for over 30 years. They would tend to view, I believe, a land acquisition proposal as the least desirable of possible solutions to their problems.

In preparation for the March 3rd meeting, I would strongly suggest that all possibe local flood protection plans be evaluated. We are not interested in a "solid gold" solution that will carry an astromonical price tag and will involve digging up half the City of Warwick. We are just looking for a local flood protection plan that will do the job.

At the meeting, if you could identify the various alternatives and evaluate their flood control effectiveness as well as their cost-effectiveness, it would be appreciated. If a particular project is viewed as not being cost-effective, would you see that the yardstick used to measure this factor is clearly explained so everyone can understand it?

If there are no effective local flood protection possibilities for the people of this area, let's at least be honest with them and tell them so. At that point, land acquisition may be the only feasible solution to the problem. If it is, how long will it take to implement it? Whatever the solution is, let's GET MOVING before we all die of old age.

Thank you for your cooperation.

Sincerely,

Edward P. Beard

Edward P. Beard
Member of Congress

EPB:nc

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDPL-B

1 March 1979

Honorable Edward P. Beard
House of Representatives
Washington, D.C. 20515

Dear Mr. Beard:

I have your letter of 12 February 1979 regarding the flooding of the Belmont (Norwood) residential area. This area is one of our deepest concerns because of the severe impact on the residents involved. Unfortunately, it is also a very difficult and costly area to protect. The purpose of my letter is to review the efforts of this office in trying to develop a way to protect the people and homes in Belmont.

Your constituent's letter refers to the loss of temporary dikes in the recent January flood. Several members of my staff were with Mayor Walsh and Belmont residents during that flood. The dikes referred to were constructed as emergency measures and were not meant to be capable of protecting against all flooding along that portion of the Pawtuxet River. One of the dikes provides relief against minor floods for the River Street-Natick Mill Village area and the other, the low-lying Belmont (Norwood) area. The dike at Natick Mill Village was built with non-Corps of Engineers funds during the construction of Interstate 295. In 1969 approximately $5,000 was spent on raising the existing dike an additional three feet to help prevent overtopping.

The Belmont dike was built as part of "Operation Foresight" in 1970. The funding source for both expenditures was under P.L. 84-99, Flood Emergency Assistance. After construction and inspection by the government, such projects are turned over to local interests for operation and maintenance. These corrective measures are not meant to be permanent solutions to the flood threats, and reconstruction is not a Federally reimbursable expense.

NEDPL-B 1 March 1979

Honorable Edward P. Beard

A reconnaissance report for the Pawtuxet River Watershed was prepared in December 1971 identifying significant flooding problems in the lower reach of the river from the mouth to upstream of the Belmont area. Floods can be caused by both river flow and high tidal surges. At the time of the reconnaissance report, the solutions under consideration were the Pontiac Diversion Complex, a hurricane barrier at the mouth of the Pawtuxet River, upstream reservoir sites at Big River Reservoir, possible modification of the existing Scituate Reservoir and various local protection projects in the lower reaches of the mainstem Pawtuxet River. The Pontiac Diversion scheme was an authorized project in 1941, but when local interests did not provide the necessary cost sharing, it was deauthorized in 1951.

New methods, as well as reevaluation of the old proposal, were investigated at the Pontiac Diversion site. Since [illegible] extensive development (Midland and Warwick Malls) has taken place along the edge of the floodplain near the intake of the Pontiac Diversion. Construction of the Pontiac Diversion proposal would aggravate flooding of both the Midland and Warwick Malls unless a local protection project were built surrounding each site.

From the preparation of up-to-date construction costs and the reality of new development in the project area, the construction cost of the Pontiac Diversion exceeded $75,000,000 for all methods investigated, far in excess of the benefits to be realized from its implementation.

Even with a major diversion of river flows, several extreme low lying areas from the Warwick Industrial Park up to and including the Belmont section would still be subjected to storm tides and thus would need some additional form of protection. A hurricane barrier across the mouth of the river proved to be economically infeasible, and was discarded in favor of some form of local protection project. The height of the protection projects would depend upon several factors, namely the height of river flooding caused by rainfall-runoff, the height of the storm driven tides and a combination of both. The studies focused on two basic measures to reduce flood damages in the basin. One was to reduce flood stages by diversion of excess flows and the second was to supplement the first with local protection for the more extreme low lying areas.

NEDPL-B 1 March 1979
Honorable Edward P. Beard

When diversion at the Pontiac location was found impractical, a new diversion site was investigated with an intake near the Natick Dam on the West Warwick-Warwick line. The 2.5 mile tunnel would discharge to the Apponaug Cove-Greenwich Bay area. This proposal, called the Natick Diversion, required considerable preliminary design efforts to develop costs. Initial foundation and material investigations indicated that the rock to be encountered was suitable for most forms of construction. The project was economically justified.

This office then formulated a flood management plan with the Natick Diversion as the key element. Because such a large volume of water could be discharged out of the basin, the necessary heights for the protection measures at the Warwick Industrial Park and the Belmont (Norwood) area would be 3' to 6' less than without the diversion in the plan. Preliminary costs in 1975 for the Belmont project, based upon a minimal earth dike cross section, was $1,100,000 exclusive of lands, damages and the internal drainage system and pumping station. The cost of the Natick Diversion was estimated in a range from $29 to $42 million depending upon the method of construction and the quality of rock along the tunnel's path. Lands and damages were not included.

These two elements, Natick Diversion and Belmont Local Protection Dike, along with the plan for the Warwick Industrial Park, were presented to the public at meetings held on 6 and 8 May 1975. When combined in a system the project had a benefit to cost ratio over 1.2 to 1.0. At these public meetings there were strong indications of support from the public and two resolutions passed by the Rhode Island Congressional interests were received in favor of continued studies of the recommended plan. The public requested further nonstructural studies and detailed information on the environmental impacts of the proposed diversion. This plan would have provided an extremely high degree of protection to virtually the entire mainstem of the Pawtuxet River.

At the conclusion of the environmental impact studies we again met with the public on 14 October 1976 recommending the same plan as previously reported. Assuming the worst possible construction conditions, including lands and damages and updating unit prices, the cost of the diversion rose to $49,000,000, an increase of 16.7 percent. The cost for the combined Warwick Industrial-Belmont Area project rose to $10,300,000, including interior drainage facilities, the costs of lands and damages, and the now required section of dike behind the American Lumber yard. The approximate cost of the Belmont section alone would be $4,000,000. When the combined project for the two local protection areas is evaluated as a system the benefit to cost ratio was slightly above unity. The benefit to cost ratio of the Belmont area alone was less than .25 to 1.0; however, we felt we could include the Belmont project within the combined system, reasoning that we would be able to use considerable material from the diversion excavation as filler material in the dike section. The Belmont dike would in essence become a spoil site for the tunnel excavation, providing an overall enhancement to the social well being of the area.

As you are aware, the results of that 14 October 1976 meeting came to us very unexpectedly. No interest spoke in favor of the diversion and only one individual spoke for the Belmont (Norwood) project. In addition, the city of Warwick informed us that they could not cost share any of the local requirements (equal to $800,000). An acceptable flood protection plan for the Pawtuxet River Basin did not seem possible. We were then asked to take one more look to see if any flood management plan could be found which did not include the diversion.

Through a series of workshops with state and local groups, new interest became apparent when the Governor of Rhode Island urged us to look at the proposed Big River Water Supply Reservoir for multi-use aspects including storage of flood waters. We have calculated the flood stage reductions due to flood storage in Big River Reservoir to be relatively minor with water level reductions of less than two feet at Belmont and only one foot at Warwick Avenue (Industrial Park). At a May 1977 public meeting we agreed to examine the feasibility of a basin plan consisting of flood storage at Big River Reservoir and local protection at Belmont and Warwick Industrial Park.

NEDPL-B 1 March 1979
Honorable Edward P. Beard

Due to the now unavailability of the free spoil material to fill up the dike and the fact that the dikes must be higher without the diversion, the costs now have risen to about $7,000,000. The local contribution would be about $1,400,000 if approved. The benefit to cost ratio for providing protection to the Belmont area alone is less than .25 to 1.0. Economically we cannot recommend this type of expenditure to protect about 70 homes and several small commercial establishments. It is far more advantageous to consider purchasing the most flood prone properties.

At present we are considering the purchase of 32 homes, all located north of First Avenue. Detailed real estate estimates have not been made but based upon our estimates when the dike was originally considered, the purchase of these homes along with acquisition of all titles in this area would be between 1.25 and 1.5 million dollars. Detailed estimates will not be undertaken until we get approval from the Chief of Engineers. This could be done during design stages. The approach we are following for the acquisition is rather unique and with limited precedent. We are presently determining the benefits for the proposal using methods which are new and non-traditional.

We plan to recommend this proposal as part of an environmentally enhancing plan where the B/C ratio may in some instances be less than unity. Cost sharing on the part of non-Federal interests will still be required and the proposal will require the support of the residents of Belmont. I believe this plan, if supported and approved by Congress, is the maximum that we, the Corps of Engineers, can offer to assist the residents of Belmont with their chronic flood problems.

Since the start of this study we have put considerable effort into resolving Belmont's flood problems. We have met with residents and officials on numerous occasions and have presented several viable alternatives that would have solved the flooding problems. The problem is difficult as protection for the Belmont

Mr. Bergen/kc/519

NEDPL-B 1 March 1979
Honorable Edward P. Beard

area by itself is not economically justified. Hopefully the acquisition which we are considering will be acceptable to the residents and will find support when the final report is submitted this coming September.

Sincerely yours,

JOHN P. CHANDLER
Colonel, Corps of Engineers
Division Engineer

CF:
Hon. Edward P. Beard
307 Post Office Annex
Providence, RI 02903

cc:
DAEN-CWZ-D

cc:
Mr. Bergen
Mr. Quinn
Reading File
Plan Div File

QUINN

DOYLE

BERGEN

IGNAZIO

BURKE

CHANDLER

Providence Journal
Providence, RI
Feb 12 1979

Belmont Park is warm to flood-plain proposal

Army engineers considering buying entire neighborhood, but that may take 5 years

By DOUG CUMMING
Journal-Bulletin Staff Writer

WARWICK — Belmont Park residents, angry about the years of flood-control paperwork that did them no good in last month's flood, reacted favorably to news that the Army Corps of Engineers is considering buying up the entire neighborhood for a flood plain.

But hearing that such a plan would take at least another four or five years seemed yet another blow to the 23 homeowners who met with city officials Saturday to discuss their flooding problem.

"I don't think anyone who lives in Belmont Park would willingly sell their homes, but what is the alternative? This is the question I've been asking for 10 years," said Barbara Della Porta of 34 Sumner Ave.

• • •

APPROXIMATELY 45 families between First Avenue and the Pawtuxet River left their homes 17 days ago when electric power was shut off and pumps could no longer keep the overflowing river from filling basements.

City Planner Barbara Sokoloff, who recounted the 10-year history of the Army Corps' involvement in the problem, told the residents that the recent flood was estimated to be a 25-year high point, using geological averages.

The meeting at the Police Station community room was held so that residents could express their feelings about the proposed acquisition before the Army engineers meet with the residents March 3 to discuss that and other proposals, Sokoloff said.

Warwick

Representing the state's congressional delegation at the meeting were Jack Riley for Rep. Edward P. Beard, Dennis Reilly for Sen. Claiborne Pell and Dave Griswold for Sen. John H. Chafee.

Riley suggested that federal acquisition would take four or five years to allow for planning, appraisals and budgeting.

Mayor Joseph Walsh explained to the congressional aides that they were invited because the residents do not feel that the Corps is doing all it can to help Belmont Park, which is in the Norwood section. A $60-million plan to divert floodwater underground into Apponaug Cove was rejected by city and state officials in 1976 as too costly. But Walsh argued that the Corps should not have extended the scope so far beyond the problem in Belmont Park.

• • •

IN 1977, with local endorsement, the Corps said it would draw up a compromise plan involving construction of dikes in flood-prone areas and the raising of a proposed dam at Big River.

A few months ago, the Corps told city officials that the diking would not be "cost effective" according to a formula the federal government uses to balance cost against benefits, Sokoloff said. They suggested acquisition instead.

Walsh told the congressional aides that acquisition was an "end of the line" solution that the residents were prepared to accept only out of frustration. He suggested that the state's congressmen should put pressure on the Corps to look at other options.

But one resident complained that too much federal money has already been thrown away on useless studies. Another, Jeannette Del Padre, said that if the Corps, at the March 3 meeting, simply says they're going to study the problem some more, "Then they're going to have a lot of violent people on their hands."

Barbara Butler of 51 Ring Ave. blasted the idea that diking the area would not be "cost effective." She asked rhetorically if preventing future floods would not be worth saving lives.

Residents complained about the smell left by oil and overflow from the sewage treatment plant upstream. Several said their foundations had been severely damaged. Others said that they were still paying off loans for repairs from previous floods, and have lost the willpower to make further repairs. The homes are impossible to sell now, one woman said.

Beard backs $7-million dike to protect property valued at $1.5 million

WARWICK — Rep Edward P. Beard, picking up the spirit of a meeting yesterday between Army Corps of Engineers officials and angry residents of flood-prone Belmont Park, proposed federal legislation to protect the neighborhood with a $7-million dike.

Beard, after listening for about two hours to a problem that the Corps has been studying for 10 years, said that he would immediately draft a bill for a dike along the Pawtuxet River in Belmont Park. In addition, he said he would seek letters from residents, photographs of past flooding and, if necessary, a busload of the flood victims for the benefit of House committee hearings in Washington.

The Corps' proposal, presented by engineer Larry Bergen at the public meeting at Aldrich Junior High School, was different from Beard's. Bergen said that the Corps, with local approval, would buy out 33 families north of First Avenue and raise that road by about two feet to protect residents on the other side of First Avenue.

The cost of creating this nine-block flood plain would be about $1.5 million, he said.

• • •

SOME 50 RESIDENTS hooted their disapproval as soon as they heard this plan. Those living south of First Avenue, which was about half of those present, said their problems would not be solved by the plan. Those living north of First Avenue complained that the moving date of 1984 or 1985 was too far off.

"We'll be dead and buried by then," one elderly lady called out. "Forget it," said another.

Bergen explained that the Corps is limited by guidelines that say costs must be justified by benefits. A plan to build dikes along the river in Belmont Park — the idea Beard said he'll [illegible]rsue — was studied by the Corps beginning in 1977, but the $7-million cost was too much, under the guidelines, for protecting $1.5-million worth of real estate, Bergen said.

Similarly, Bergen said he didn't think he could get approval on a proposal to acquire any more than 33 homes.

"There's a limit to what we can justify," he said.

Mayor Joseph Walsh criticized the Corps' purely economic analysis for ignoring the human element involved, "the hardship and tragedy" of flooding that has [illegible] these middle class residents thousands in home repairs. The Corps' study began in 1969 because of the Belmont Park problem, but expanded into a much wider $59-million proposal, which was rejected locally because of the cost. Two years ago, when the dike would have only cost $3 million, that plan was scrapped by the Corps as not being cost effective.

• • •

WALSH ALSO criticized the Corps for planning a $10-million dike around the Warwick Industrial Park but not around a residential area. "If you're looking for 20 percent from us on that $10 million for the industrial park I'll save you the money for all those studies, because we're not going to do it," he said.

Meanwhile, Walsh said that city and state officials would soon m[illegible] to w[illegible] out a temporary solution, [illegible]ging, in case of spring floods.

Richard F. Quinn, another engineer for the Corps, said that the raising of First Avenue by two feet coupled with the extra two feet of water which would be stored by the proposed Big River Reservoir project would g[illegible] residents south of First Avenue four more feet of protection than they had during the January flood.

But Larry Colvin of 74 Sumner St. said that the raising of First Avenue wouldn't do anything but keep the water in his yard, since the water gets there in the first place by underground seepage.

Others pointed out that the Big River Reservoir project, which Quinn said might be ready sometime between 1988 and 1990, may never be completed because voters have continually rejected the idea in bond referenda.

• • •

REPRESENTATIVES from the offices of Governor Garrahy, Sen. Claiborne Pell, Sen. John Chafee and Rep. Fernand St Germain were also at the meeting.

The crowd expressed its feelings loudly, as when everyone cheered at the mention of Warwick sponsoring bus rides down to Washington and being taken out to lunch en masse with Representative Beard.

"I've got a solution," said Evelina Vitale of 25 Sumner St. to the Corps engineers. "You send somebody to live in our neighborhood until the problem is solved."

April 11, 1979

Colonel John P. Chandler
Army Corps of Engineers
424 Trapelo Road
Waltham, Mass., 02154

Dear Colonel Chandler:

Enclosed is the petition requested by Mr.Quinn at the meeting held at Aldrich Junior High School in March regarding the Corps' latest proposal for acquisition of the homes in Belmont Park. I would like to know whether the Corps has made a decision on the question of including any of the homes on the south side of First Avenue in their acquisition plans, and also if they are going to continue the survey of the damages incurred by all the residents of the area.

Thank you for your continued support on our behalf.

Sincerely yours,

Barbara L. Della Porta

Mrs. Barbara L. Della Porta
34 Sumner Avenue
Warwick, R. I., 02888

Enclosure

March 12, 1979

Colonel John P. Chandler
Corps of Army Engineers
424 Trapelo Road
Waltham, Mass., 02154

Dear Colonel Chandler:

We, the residents of the Belmont Park section of Warwick Rhode Island, do hereby give our approval of the Corps' plan for acquisition of our homes if building a dike to protect our neighborhood is not feasible any longer. We urge the Corps to speed up the time involved in this plan because we are still unprotected from the ravages of the Pawtuxet River.

Betty Pierce 45 Sumner Ave. Warwick

Barbara L. [illegible] 54 Sumner Ave Warwick

John T. Pierce 45 Sumner Ave, Warwick

[illegible] Warwick

Linda S. Zuncler 57 First Ave Warwick

Lawrence L. Colvin 46 Wingate Ave Warwick RI

Matilda Colvin 46 Wingate Ave, Warwick RI

Irene Kilduff 46 King Ave War RI

[illegible], 54 Iona Ave, Warwick, RI

Jeannette Del [illegible], 70 King Ave, Warwick R.I.

Theresa Bouchard, 76 King Ave, Warwick, R.I.

John J. Kilgallen III 1746 Elmwood Ave Warwick, RI

Ethel [illegible] Thomas - 1746 Elmwood Ave - Land on Iona Ave

Sandra Colvin - 24 Sumner Ave Warwick

Lawrence Colvin Jr. 24 Sumner Ave Warwick

Catherine [illegible] 66 King Ave Warwick

[illegible] Fleming 115 [illegible]

Albert L. Zuncler 55 First Ave Warwick

Rita Dunlap [illegible]

Ida Cochrane 24 Wingate Ave Warwick, R.I.

Louis Colvin 54 Sumner Ave Warwick R.I.

Anna C. Colucci 84 Sumner Ave, Warwick R.I.
Jeanette Cole 14 Wingate Ave. Warwick R.I.
Walter Leonard Sr. 57 King Ave - Warwick, R.I.
Flora Leonard 57 King Ave. - Warwick, R.I.
[illegible] C. [illegible] - 30 Sumner Ave. - Warwick, R.I.
Clayotha & [illegible] - 96 First Avenue - Warwick RI.
Julia Schmidt 45 Sumner Ave
Esther Correia 25 Sumner Ave Warwick R.I.
Richard Correia 25 Sumner Ave Warwick R.I.
Mr Thomas R. Doucette Jr 18 King Ave Warwick, R.I.
Frank [illegible] [illegible] R.I.
Beverly Normandin 34 Iona Ave Warwick, R.I.
Joseph F. Kilduff III 58 Iona Ave Warwick, R.I.
Raymond F. Hicks 91 Iona Ave Warwick R.I.
Mr & Mrs Howard Johnston 109 King Ave Warwick, R.I.
Mr & Mrs [illegible] 52 [illegible]
Mr & Mrs [illegible] 58 Wingate Ave Wa. R.I.
Mr. & Mrs. John E. Parker Jr. 65 Wingate Ave. Warwick, R.I.
Mr & Mrs Robert [illegible] 79 King Ave Warwick
Mr. Robt R [illegible] 33 [illegible] Warwick, R.I.
Mrs & Mr Thomas Gile 26 Heath Ave, Warwick
[illegible] 31 Heath Ave Warwick R.I.
William Leonard 31 Heath Ave Warwick R.I.
[illegible] 51 King Ave Warwick R.I.

EDWARD P. BEARD
2D DISTRICT, RHODE ISLAND

MEMBER:
COMMITTEE ON EDUCATION AND LABOR
SUBCOMMITTEE ON SELECT EDUCATION

CHAIRMAN:
SUBCOMMITTEE ON LABOR STANDARDS

Congress of the United States
House of Representatives
Washington, D.C. 20515

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307 POST OFFICE ANNEX
PROVIDENCE, RHODE ISLAND 02901
(401) 528-4861

Providence, R. I.
January 29, 1980

Colonel Max B. Scheider, Division Engineer
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Scheider:

It is my understanding that the Washington office of the Corps has given the New England Division two options relative to the proposed acquisition project in the Norwood-Belmont area of Warwick.

1. To include it in the report on the Big River Reservoir Project.

2. To submit it to the Small Projects Section of the Washington office of the Corps.

Since the first option will take a great deal of time, I trust that the second option will be pursued. Even if this is followed at the standard rate, it may be two to three years before the first house in this area is actually purchased. This time frame is totally unacceptable. The people in this section of Warwick have been suffering with flood conditions for many years and the Army Corps of Engineers has been studying the problem for well over ten years.

It seems to me that the time for action is at hand. Since the Washington office of the Corps has already approved the basic concept of acquisition, I would respectfully request

Colonel Max B. Scheider, Division Engineer
Page 2
January 29, 1980

that this project be given the greatest possible priority and that all necessary resources be directed toward executing the $2.2 million acquisition plan as quickly as possible.

Kindly send all correspondence in this matter to my Providence office.

Sincerely,

Edward P. Beard

Edward P. Beard
Member of Congress

EPB:na

APPENDIX 4

ENGINEERING INVESTIGATION, DESIGNS AND COST ESTIMATES

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TABLES

PLATES

FIGURES

NATICK DIVERSION

Major components of the diversion would consist of intake and outlet works interconnected by a deep underground tunnel (as shown on the profile on Plate 9 of the original hydrologic analysis). Similarly, the diversion intake works, Plate 10, would be composed of two new concrete structural elements consisting of an intake inlet and a regulating dam to be located about 100 feet downstream of the intake inlet or 200 feet from the existing Natick Pond Dam. The intake works (section shown on Plate 12) would consist of an inverted trumpet shaped weir, commonly referred to as a "morning glory spillway" having an effective crest length of 240 feet and its lip (crest) at elevation 38.0 feet, mean sea level (msl), or approximately 10 feet above the existing riverbed. Its maximum diameter measured across the crest would be about 77 feet, tapering to the final tunnel diameter at the transition point. See plates 10, 11 and 12 of the initial hydrologic analysis reports for pertinent information.

The regulating dam would act as a control structure. It would consist of an overflow weir, a non-overflow structure and an emergency spillway. The weir section, ogee in shape and having its crest at elevation 48.0 feet, msl, would measure 115 feet in length. The non-overflow section, 30 feet in length and located northerly of and 3 feet higher than the overflow weir, would contain two 8 feet by 8 feet sluice gates for controlling normal Pawtuxet River flows. A small spillway channel 65 feet in length and located adjacent to the structure at approximately elevation 50 feet, msl, would act as a relief valve to pass excess river flows during an extreme emergency. This condition would only occur after the diversion-tunnel and the overflow weir have exceeded their designed capacities.

Existing Natick Dam, located 100 feet upstream of the intake and having a crest elevation of 48.6 feet, msl, would remain intact. From field observation it appears structurally sound, but could be modified at a minimum cost in the final design stage if further detailed studies reveal a need to do so. An artist rendition of the intake works is shown on the following page.

The subsurface tunnel, (as shown on Plate 9), connecting the intake and outlet works in a nearly straight 2.5 miles (13,200 feet) southeasterly alignment would be driven through bedrock and would have a finished inside diameter equal to that of the considered alternative. A typical section of tunnel is shown on in the original hydrologic analysis. This interior finish would consist of a 12-inch reinforced concrete lining, anchor-bolted to the finished rock walls. The tunnel invert (floor level) at the intake shaft will be -75 feet, msl, and will slope at 0.0103 feet per foot to elevation -210 feet, msl, at the outlet works. With the design discharge of 13,000 cfs and a Mannings' "n" value of 0.015 as roughness coefficient, the velocity of flow in the tunnel will be 18 feet per second (fps).

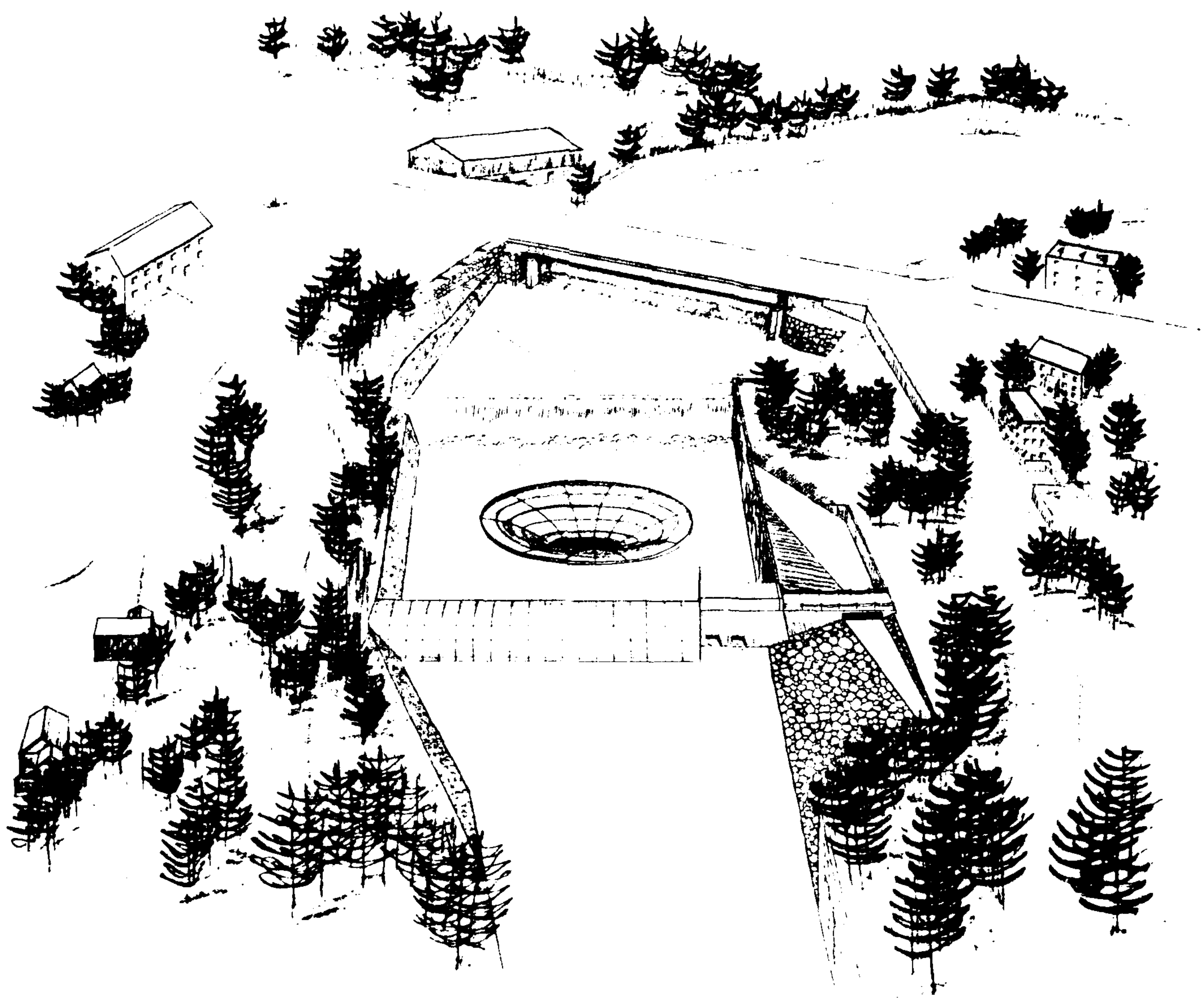
The outlet works, Plate 11, with an artist rendition shown, will be located on lands off Station Street which runs nearly parallel to, and about 100 feet west of the ConRail Boston to New York main line railroad tracks in the vicinity of Apponaug Cove in Warwick. At this point, the Pawtuxet River flood waters will be dispersed into the Cove. The outlet structure, Plate 12, would be a reverse "morning glory" spillway, atop the selected tunnel's vertical shaft, transitioning to a 114-foot horizontal width concrete apron. By placing a concrete wall around the "morning glory", floodwater flows leaving the outlet shaft would be directed toward the existing Federal naviation channel. The length of the enclosing wall would be about 260 feet with top elevation at 12 feet, msl.

The bottom of Apponaug Cove would be protected from excessive scour or the erosive effect of flows over the spillway by an armor stone apron extending along the bottom 100 feet by an armor stone apron extending along the bottom 100 feet outward from the spillway. The outlet end sill will be at elevation -4 feet, msl, and equipped with a stoplog structure to permit or facilitate dewatering (pumping out) the tunnel for periodic inspection and maintenance. Under design discharge conditions, and for all tides below approximately +10 feet, msl, 90 foot clear span openings between the piers of the stoplog structure at the end sill of the outlet will be the hydraulic control.

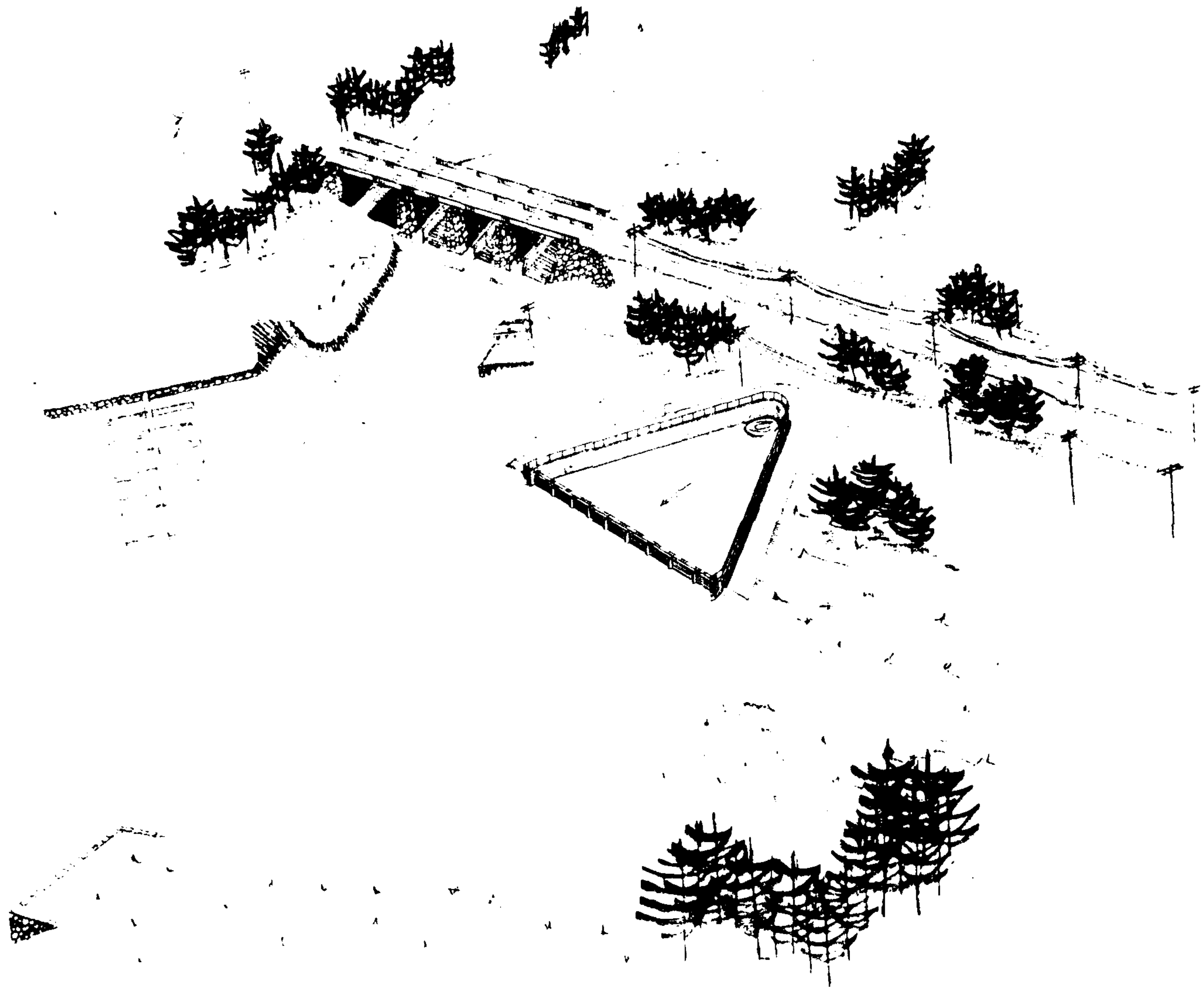
Outlet discharges from the diversion tunnel will flow through Apponaug Cove for a distance of approximately 4,500 feet, thence to Narragansett Bay via Greenwich Bay. As analyzed, the hydraulic head loss representing the energy losses throughout the length of the cove would be a maximum with diversion during low tide. Therefore, the hydraulic effects of the Natick Diversion upon the cove would be minimal under low tide (mean low water) conditions and negligible under spring tides and a 10-year frequency tide (one having a 10 percent chance of occurring in any one given year). Hydraulic head loss and maximum velocity in the navigation channel through the cove for different tides and diversion rates are listed in Table 4-1.

The effects of three diversion rates in conjunction with three tidal events are demonstrated in Figure 4-1 preceding Table 4-1. The following paragraphs describe the relationship of a mean low water condition to various diversion rates along the center line of the Apponaug Cove navigational channel.

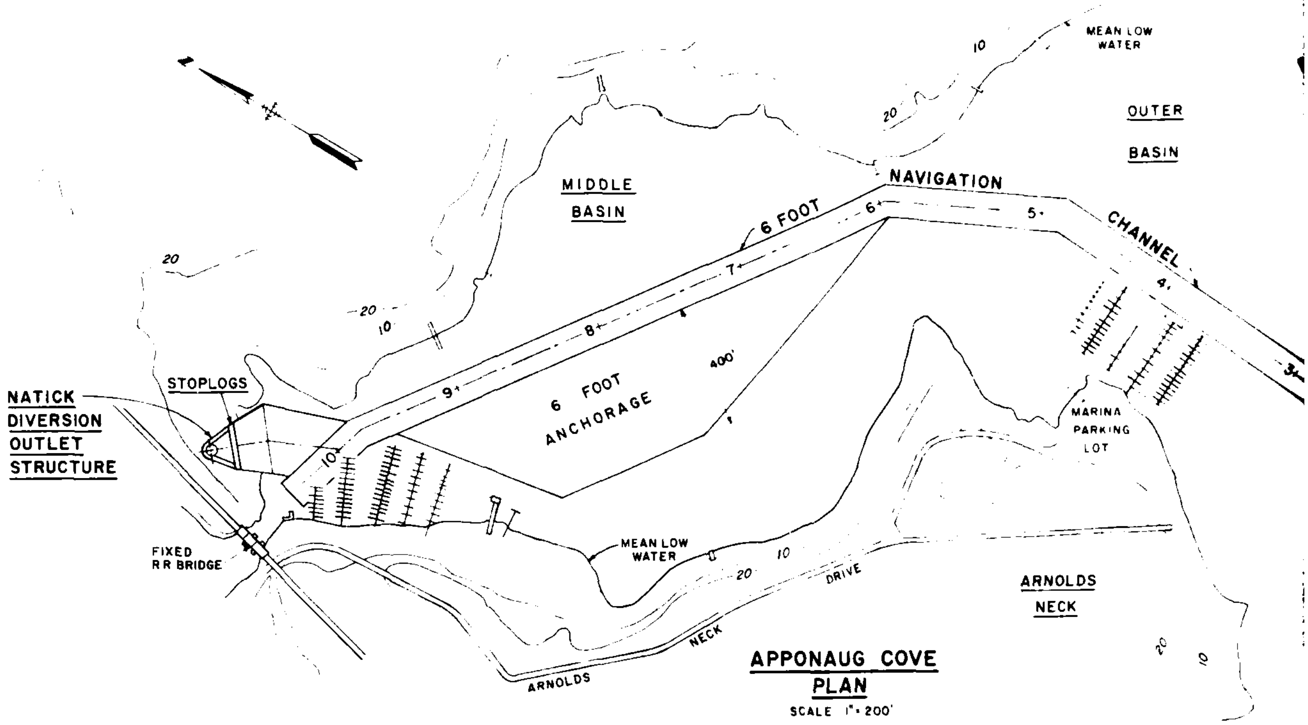
The increase in water surfaces at the outlet channel (Station 3+30) would be a maximum of 3.0 feet with a diversion rate of 13,000 cfs. This water surface level would remain almost constant for a distance of 1,480 feet outward (Station 18+30), then taper off to mean low water elevation within a distance of 2,520 feet (Station 43+50). With the remaining two diversion rates, changes in water surface levels would occur within the same limits but increased levels at the outlet works would be 1.5 feet for 8,000 cfs flow and 0.4 feet for 3,000 cfs.



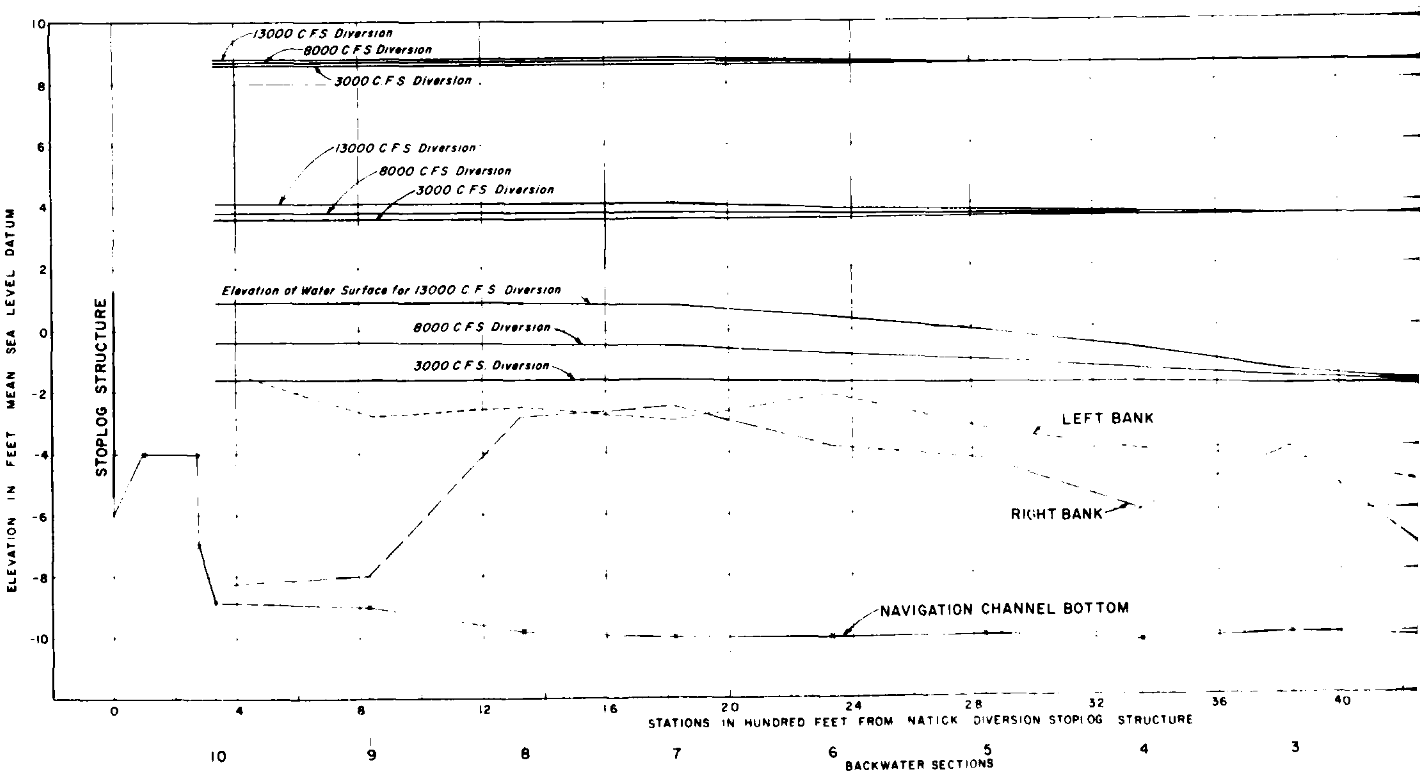
NATICK DIVERSION INTAKE WORKS



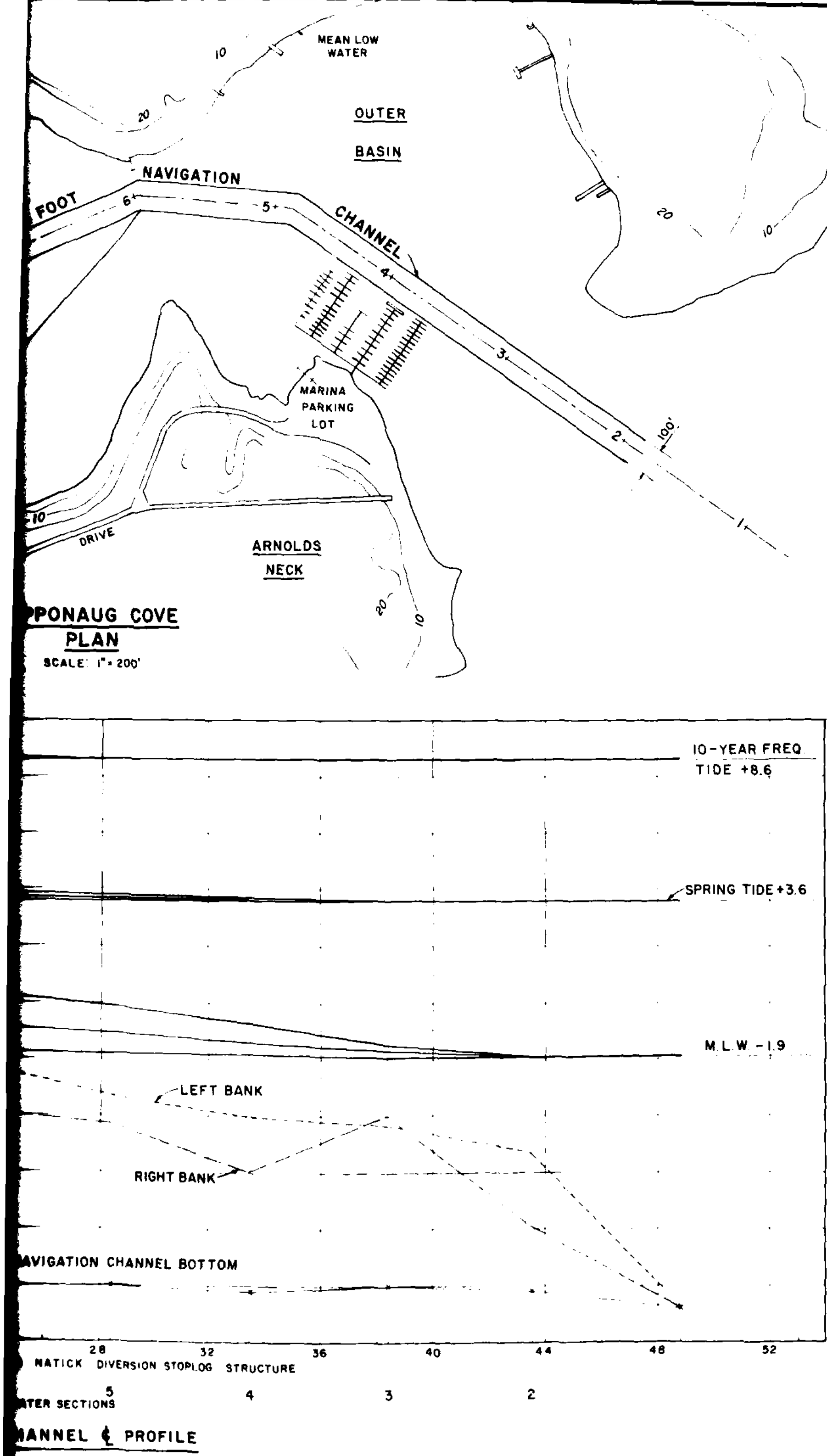
NATICK DIVERSION OUTLET WORKS



APPONAUG COVE
PLAN
SCALE 1" = 200'



NAVIGATION CHANNEL ℄ PROFILE
SCALE HOR 1" = 200'
VER 1" = 2'



NOTE:

1. ALL ELEVATIONS REFERENCED TO MEAN SEA LEVEL DATUM
2. NUMERAL ON ℄ OF NAVIGATION CHANNEL PLAN INDICATE BACKWATER CROSS-SECTIONS NUMBER

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

NATICK DIVERSION

EFFECTS OF DIVERSION FLOWS

ALONG NAVIGATION CHANNEL APPONAUG COVE

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

FIGURE 4-1

TABLE 4-1

HYDRAULICS OF APPONAUG COVE

TIDE LEVEL (ft msl)	DIVERSION RATE (cfs)	HEAD LOSS* IN COVE (ft)	MAXIMUM VELOCITY IN CHANNEL (ft/sec)	(knots)
Mean Low Water	13,000	3.0	8.0	4.7
-1.9	8,000	1.5	5.5	3.3
	3,000	0.4	2.3	1.4
Spring Tide				
+3.6	13,000	0.4	4.4	2.6
	8,000	0.2	2.7	1.6
	3,000	Negligible	1.0	0.6
10-year Frequency Tide				
+8.6	13,000	0.2	2.7	1.6
	8,000	Negligible	1.5	0.9
	3,000	Negligible	0.6	0.4

* Represents increases in water surface levels.

The analysis indicates that for the other two conditions shown, namely the spring tide and 10-year frequency tide events (See Figure 4-1); various diversion rates have insignificant effect on the cove.

With the design flow of 13,000 cfs, the velocity in the vertical shaft will be approximately 18 fps. Water surface at the top of the shaft would rise to near the energy gradient of +10 feet, msl, and then drop to about critical depth elevation of +6 feet, msl, through the piers on the outlet sill. A critical depth of 9 feet with velocities of 19 fps would occur through these piers. Head loss through the outlet structure, including one velocity head loss, was estimated to be approximately 7 feet.

The operation of the diversion would be accomplished as follows:

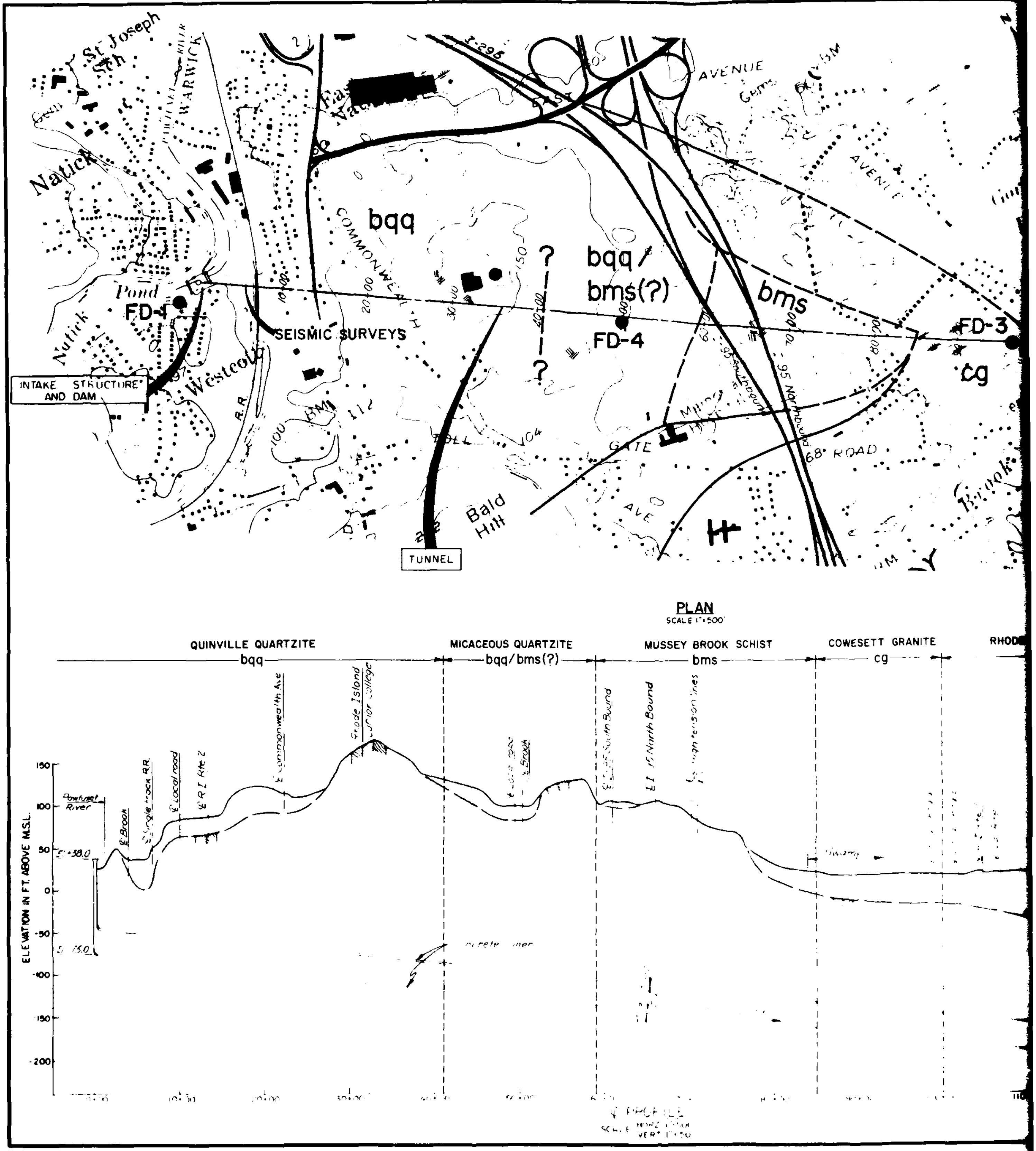
During normal river flows, the sluice gates in the non-overflow section of the regulating dam would remain open to permit passage of normal Pawtuxet River flows past the project. When a flood stage becomes imminent, the sluice gates would be closed allowing water to build up behind the regulation dam. When this water level reaches an elevation of 38.0 feet, mean sea level, it would spill into the morning glory spillway and be diverted into Apponaug Cove via the tunnel.

Should the Pawtuxet River flood flow exceed the diversion capacity the water level behind the regulating dam would rise until it flows over the overflow section of the regulating dam and continues downstream along the Pawtuxet River. The emergency spillway of the regulating dam is provided to pass flows exceeding the capacity of the overflow section should this rare event be exceeded.

The diversion would operate on the principle of an inverted siphon with the outlet tunnel and a portion of the intake shaft inundated with salt water. However, under no circumstances could salt water intrude the fresh water of the Pawtuxet River. Provisions would be made for continual withdrawal of this salt water by pumping to prevent anaerobic conditions and/or the occurrence of hydrogen sulfide gas.

Geotechnical Features - Surficial and subsurface investigations were conducted to determine general foundation conditions, such as extent and type of overburden, depths to and types of bedrock at grade and levels of subsurfacewater. Foundation explorations consisted of four core borings and a seismic survey for the tunnel alignment.

Explorations involving the diversion component were performed primarily to define the depths to and type of bedrock at tunnel grade and to obtain core samples for determination of rock quality shown on Plate 4-1. These investigations consisted of four core borings along the



St Joseph
Natick
Pond
FD-1
INTAKE STRUCTURE AND DAM
Westcott
SEISMIC SURVEYS
COMMONWEALTH
bqq
?
bqq / bms(?)
bms
FD-4
FD-3
cg
I-295
AVENUE
GATE
ROAD
Bald Hill
TUNNEL
PLAN
SCALE 1"=500'
QUINVILLE QUARTZITE
bqq
MICACEOUS QUARTZITE
bqq/bms(?)
MUSSEY BROOK SCHIST
bms
COWESETT GRANITE
cg
ELEVATION IN FT. ABOVE M.S.L.
150
100
50
0
-50
-100
-150
-200
Pawtuxet River
℄ Brook
℄ Single track R.R.
℄ Local road
℄ R.I. Rte 2
℄ Commonwealth Ave
Rhode Island Junior College
℄ I-95 North Bound
℄ PROFILE

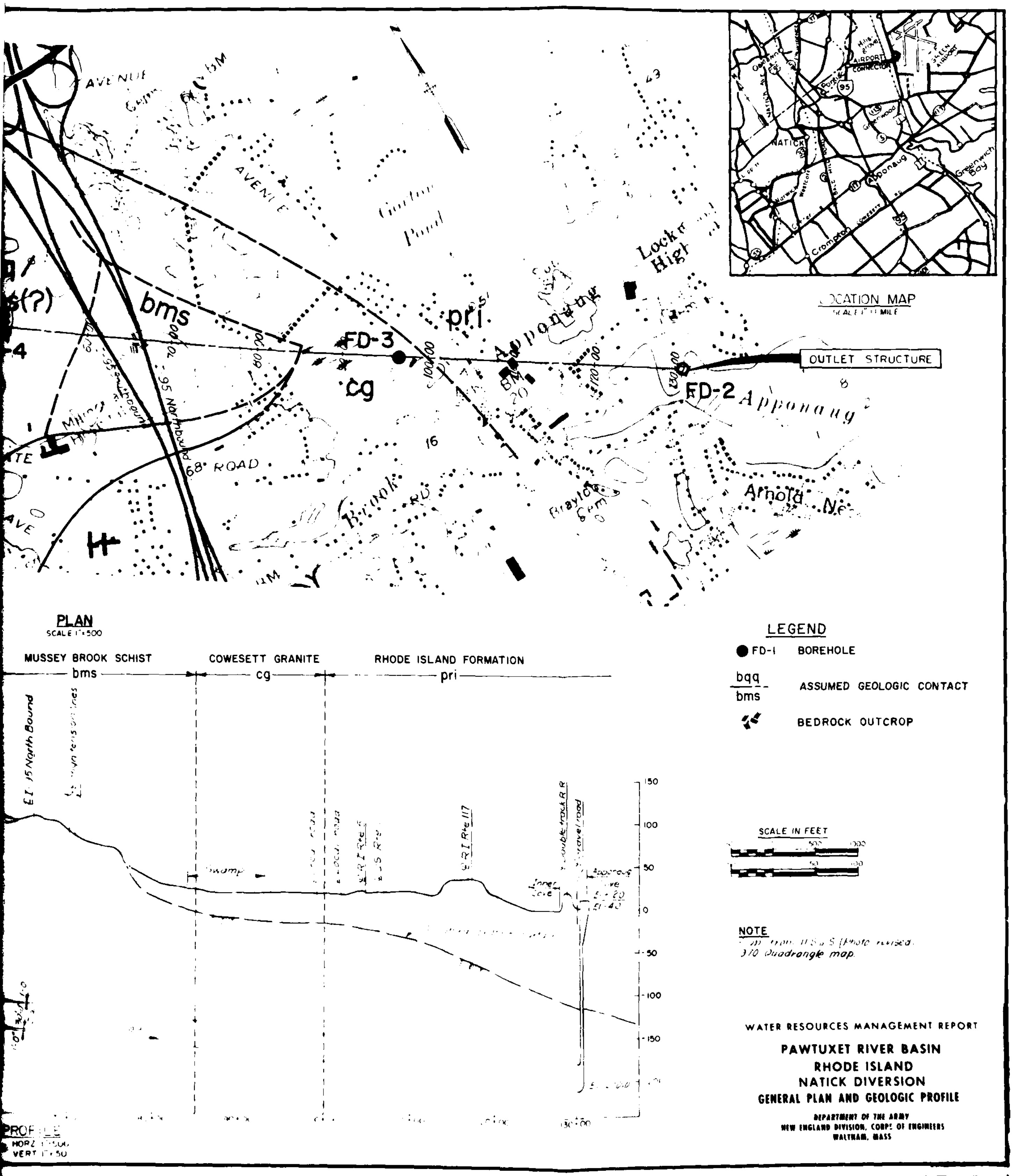

OUTLET STRUCTURE
FD-3
FD-2
bms
cg
pri
Appona ug
Arnold
ROAD
PLAN
SCALE 1"=500
MUSSEY BROOK SCHIST
bms
COWESETT GRANITE
cg
RHODE ISLAND FORMATION
pri
LEGEND
FD-1 BOREHOLE
bqq
bms
ASSUMED GEOLOGIC CONTACT
BEDROCK OUTCROP
SCALE IN FEET
NOTE
Quadrangle map.
150
100
50
0
-50
-100
-150
PROFILE
WATER RESOURCES MANAGEMENT REPORT
PAWTUXET RIVER BASIN
RHODE ISLAND
NATICK DIVERSION
GENERAL PLAN AND GEOLOGIC PROFILE
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

PLATE 4-1

tunnel axis and a seismic survey for a selected area. The seismic survey was performed in the saddle along the alignment about 500 feet downstream (southeasterly) from the intake structure and adjacent to the railroad tracks, to determine depths of bedrock or minimum rock cover above the tunnel crown at this location. The maximum rock cover above the tunnel crown is approximately 255 feet occurring near the Rhode Island Junior College, with a minimum of about 50 feet at the previously mentioned railroad tracks. Exclusive of the first 800 feet from the intake where the minimum amount of clearance between the tunnel crown and ground surface approximates 70 feet, there are no other points with less than 130 feet of vertical clearance.

All structures inclusive of tunnel would be either constructed or anchored in rock. The tunnel is considered to cross four major rock formations with their physical properties and structural characteristics described in Table 4-2. They are the Quinville Quartzite, a micaceous quartzite part of either the Quineville or the Mussey Brook Schist, the Cowsett Granite, and the Rhode Island Formation. As the exact locations of the contacts are unknown, assumed contacts are based on interpretations of data from core borings, literature survey and existing maps. The section of the tunnel at the outlet end of the alignment passes beneath the margin of a buried valley which is assumed to deepen eastward toward Apponaug Cove.

All boreholes, except one, were pressure tested to determine inflow characteristics for future construction purposes. Core rock samples from each of the borings were classified and laboratory tested for strength and other properties to evaluate general tunneling and foundation characteristics. Tests included unconfined compressive strength testing of representative cores, RQD determinations and sling friction tests for a natural and sawed joint on samples at tunnel grade drom boring FD-4. Overburden samples were also examined and visually classified to determine soil characteristics above the tunnel and at shaft locations. The test results equated to the rock formations are shown on Table 4-2.

Subsurface water occurs in the overburden and in rock. The level of the water table generally varies at shallow depth in the ground with the ground topography tending to rise under the hills and drop in valleys. Where the water table intersects the ground surface, springs and swamps may form. Except at the outlet end of the alignment, the greater part of the tunnel will be overlain by rock with a thin overburden cover. In this situation the occurrence of the groundwater in the rock will vary with the permeability of weathered and fractured zones. At the outlet end, the thickness of overburden gradually exceeds the thickness or rock above the tunnel. The overburden is permeable and would be saturated to sea level. Ground water in the rock would be in open joints and weathered zones.

TABLE 4-2

SUMMARY OF ROCK CHARACTERISTICS

Formation Description	Core Recovery %	RQD[1)]	Pressure Test Results	Depth of Sample (Ft)	Unconfined Compressive Strength (psi)	Remarks
Quinville Quartzite (boring FD-1) Very hard, massive, generally unweathered; joints are scattered; slickensides present.	98.7	90	Borehole tight	46.1-46.9 (2 tests) 60.7-61.4 68.6-69.5 83.7-84.6 (2 tests)	10,650 (1) 13,070 (2) 15,530 16,850 16,140 (1) 16,020 (2)	Joints and planes of weakness dip from 35 to 55 degrees but mostly at 50 degrees. Considered moderately hard to excavate. Overbreak will be controlled by local jointing.
Micaceous Quartzite, unknown formation (boring FD-4). Very hard to hard, massive, generally unweathered; locally foliated and schistose; slickensides and thin calcareous seams common.	98.3	87	Borehole tight	154.6-155.3 175.3-176.2 178.1-178.7 195.0-195.8 169.3-173.4 (Sawed joint) 172.3-173.4 (Natural joint)	7,040 610 4,600 8,020 $\phi = 26^{\circ}$ (sliding friction) $\phi = 32^{\circ}$ (sliding friction)	Most joints and breaks dip 30 to 65 degrees. Foliation and schistosity dip between 30 and 50 degrees. Tested specimens failed along healed joints and fractures. Considered moderately hard to excavate. Overbreak will be controlled by intensity of fractures.
Mussey Brook Schist Hard to very hard interbedded chlorite quartz schist, quartzite, mica schist, and quartz-mica schist; irregular jointing; variably foliated.	--	--	--	Not drilled	4,000 (weakest beds) 16,000 (strongest beds) (Assumed values)	Observed in outcrop. Beds are thin, strongly to weakly foliated, variably jointed. Considered relatively easy to excavate. Overbreak will vary with rock type and orientation of foliation.
Cowesett Granite (boring FD-3) Hard, gray and pink granite; occasional joints and slickensides; occasional weathered zones; scattered micaceous partings.	98.3	67	Borehole tight	38.9-39.4 49.5-50.1 51.6-52.1	4,820 17,780 17.700	Most joints and breaks dip between 30 and 60 degrees. Local weathered zones may be present. Excavation considered moderately hard. Overbreak will probably be minimal except at local fractured zones.
Rhode Island Formation (boring FD-2) Hard and moderately hard interlayered quartzite and schists; strong foliation and bedding; generally slight and localized; slightly calcareous	90.9	*	Borehole tight	151.2-151.9 180.0-181.5 184.1-184.8	5,110 9,740 3,250	Foliation and bedding dip 35°. Testing performed using bx diameter cores. Excavation considered easy. Overbreak will vary with foliation and contacts. *RQD - Impractical to estimate because of small diameter core.

1) Rock Quality Designation

As pressure tests of the boreholes indicate that the rock is tight, heavy seepage is expected to occur only in local zones. The methods of controling seepage during construction would be moderate and would depend upon the rate of inflow at particular rock structure.

Any deep rock wells along the alignment and closely adjacent to it could be affected by the tunnel drawing down the water table during construction, and alternative sources of water would have to be provided should it be determined in the advanced design stage that, contrary to current findings, private well systems exist in the area. With the present design, after construction, salt or brackish water from Apponaug Cove would be free to fill the tunnel through the outlet structure. A water tight lining will be required to reduce the contamination of the ground water.

On the basis of preliminary subsurface explorations and testing, the Natick Diversion project appears practical based on geologic considerations. The foundation conditions for the structures, shafts and tunnel generally are adequate although problem conditions in the rock can be expected in local zones, and will be explored in further detail during detailed design. Unanticipated conditions should be limited and would require minor designs for corrective structural measures during construction appropriate to their severity.

A major portion of the Quinville Quartzite Formation and the Cowesett Granite showed preliminary strength and durability characteristics of a quality indicating that should a machined tunnel (mole) be utilized for excavation, the tunnel could probably be left unlined and provided a structural sound, smooth interior shape. Current studies indicate machine tunneling methods could be used throughout the tunnel with approximately 57 percent of the tunnel requiring a light steel support and a formed concrete lining to provide asmooth hydraulic surface. However, the considerations of the economics of construction and design including the uncertainty as to the availability of a proper mole diameter and the potential requirements for containing brackish or salt water in the tunnel precluded, at this stage of the study, the practicality of such a method.

<u>Real Estate Acquisition</u> - One home to be purchased outright is located at the intake works. In addition, a wood frame fisherman's shack including a wood timber bulkhead sea wall will be purchased at the outlet works location.

Permanent subsurface easements will be required to construct the tunnel under 50 parcels of land of which 35 are privately held and 15 under public domain, currently controlled at various locations by the city of Warwick and the State of Rhode Island.

Tunnel alignment would totally or partially beneath 2 commercial, 6 residential and 4 publi uildings. As shown on Plate 4-1, the minimum amount of vertical clea between the tunnel crown and ground surface would approximate 70 fe , occurring with 800 feet of the intake works with the remaining port n being no less than 130 feet of vertical clearance. As the tunn is over 200 feet, below ground level, the amount of damages for t deep subsurface easements would be nominal. The estimated easement lues are based on the assumption that construction methods of tunnelling will be of the blasting magnitude that would not adversely affect surface or near surface in-ground improvements.

Temporary easements, as provision for providing space for the storage of materials, equipment nd contractor's work area during construction, would also be required. Required acreage has been selected at ownerships that are unimprove lands but still contiguous to the proposed permanent easement areas Cost of temporary easement are predicated upon a fair return of invested capital (fair market value) and a provision for estimated economic tax for the use of the land during the construction period. Temporary easements would involve 2.56 acres located in West Warwick and 2.8 acres in Warwick.

Tunnel alignment would proceed beneath a fairly high-density mixed-use area. Preliminary investigations indicate that after the imposition of the easements, the highest and best use of all the properties affected by this proposed acquisition tunnel program will not be materially affected. However, it is historically known that the mere knowledge and existence of the imposition infers a restrictive aspect of a perpetual cloud on the title which runs with the property. Affected lands (1.00 acres) at the diversion outlet are currently vacant under a single ownership and front along Apponaug Cove in a generally commercial, industrial area with some waterfront recrational uses nearby.

The outlet would be located in the most marshy low part of the land and although it is locally zoned for industrial use by the city, it is classified as lying in a hurricane danger zone, which requires all buildings to be built 14 feet above msl. Construction in coastal areas is governed by rules and regulations of the local government. Coastal development is also regulated by the State Coastal Resources Management Council for environmental protection. In addition to land acquisition, a small fisherman's shack as previously stated, with an old wood timber sea wall which occupies the southerly end of the property would be acquired in fee.

At the intake works of the diversion, the affected fee land (0.98 acres) in West Warwick is under a single ownership and locally zoned for industrial uses. It contains the foundation ruins of a razed mill with

abandoned tailrace recently filled with random earth fill. Land is currently vacant and partially overgrown with second growth trees with a section presently used for storing junk vehicles and related parts. On the Warwick side of the river, or the south bank, the land area (0.82 acres) is steeply sloped and wooded, consisting mostly of vacant residential lots owned in part by the city of Warwick and in part by two private owners. The land is presently unimproved residential lots with the exception of one older existing dwelling along the ridge line. As stated in a preceeding paragraph, this is the only dwelling within the intake area that would be purchased.

A total of 43 ownerships, inclusive of one improvement, at a cost of $102,400 is in conjunction with the Natick Diversion.

To provide for possible appreciation of property values from the time of this acquisition date, for possible minor property line adjustments or for additional hiden ownerships which may be developed by refinement of taking lines, for adverse condemnation awards and to allow for practical and realistic negotiations, a contingency allowance of 20 percent has been considered to be a reasonably adequate.

Total cost of lands and damages involving lands in fee and improvements, permanent and temporary construction easements, severance damages, relocation assistance and acquisition costs including contingencies for possible appreciation of property value are estimated at $380,800. These costs are summarized in Table 4-3 by category.

Right-of-Ways The right-of-ways for the diversion intake works would involve the lands substantially located between Water Street in West Warwick and O'Donnell Street in Warwick, with an easterly limit beginning at Natick Dam in Warwick and a line jogging in an easterly direction to Providence Street bridge in West Warwick, from which an easterly maximum distance would approximate 400 feet. Involved right-of-way lands for the outlet works would be a triangular shaped area located easterly on the ConRail Boston to New York main line railroad tracks and Apponaug Cove. The base of the triangle would be perpendicular to the tracks and about 180 feet in length with its height, measured along a parallel course with the tracks, being about 300 feet. Permanent sursurface easements for tunnel alignment on 50 parcels of lands, of which 35 are private held and 15 under public domain, would complement the required right-of-ways for operation and maintenance of the diversion project.

At the intake works, lands on the northerly bank in West Warwick are zoned for industrial use with those on the southerly bank in Warwick classified as residential with size, shape, topography and location precluding any other usage. The land at the outlet at Apponaug Cove is zoned as industrial with water front recreational value but subject to tidal flooding.

TABLE 4-3

NATICK DIVERSION

LANDS AND DAMAGES
TOTAL COSTS

	NATICK DIVERSION
Lands and Improvements (Fee/Permanent Easement)	$ 116,700
Temporary Construction Easements	80,300
Severance Damages	-
Acquisition Costs	102,400
Relocation Assistance Costs	16,500
Contingencies	64,900
TOTAL LANDS AND DAMAGES COSTS	$ 380,800

Access to the intake works would be provided via Water Street, currently an existing unpaved right-of-way along the northerly bank in West Warwick. The opposite or southerly bank consisting of a steeply sloped and wooded area in Warwick can be reached by a two-lane paved road running parallel to the river bank and currently known as O'Donnell Avenue. At the outlet works, access would be via a narrow unpaved gravel public right-of-way (Station Street), which terminates at Apponaug Cove. As access to the project area can be provided via public ways, additional right-of-way lands are considered minimal, if any.

Loss of Taxes Discussions with local assessors and a review of the community records indicate the tax loss on fee simple taking, as a result of the project, would be about $4400 per annum.

Construction Period It is envisioned that the Natick Diversion would be constructed in three general stages, the first phase being the sinking of the outlet shaft and tunnel excavation including the reinforced concrete lining. Work would be performed around the clock accommodating 3-8 hour shifts, 6 days per week. This phase will run for the first three consecutive years into the fourth.

The following phase would be the sinking of the inlet shaft along with simultaneous construction of above ground structures at the outlet. The last stage would involve the construction of the intake works. Work for these last two phases would be scheduled for 1-8 hour shift, 5 days per week. By maintaining a tight work schedule with overlap into construction stages, total construction could be effectively completed within a four-year construction period.

Operation and Maintenance As three communities, namely, the town of West Warwick and the cities of Cranston and Warwick would benefit from the Natick Diversion, the project is considered regional in nature and would be totally Federally funded under the current legislated policy.

Consequently, the cost for operation and maintenance (about $115,000 annually) including all related functions such as necessary flood control operations and collection of hydrological data would be borne by the Federal Government. Costs of dewatering the tunnel periodically for inspection purposes would also be a Federal cost.

Major Replacements This would include an allowance for project items deemed to have a usable life less than that of the project. Major items considered within this purview included sluice gates at the diversion intake of gravity outlets. From previous experience with similar projects, it is assumed that, on the average, major replacements would occur every 25 years and 90 percent of these replacement items would be required. These are estimated to be $1,200 for the diversion.

Beautification and Recreation The plan would insure that all project components be as visually acceptable as possible with inclusion of beautification and landscaping measures being an integral part of the selected plan.

Recreational opportunities associated with the Natick Diversion project are either non-existent or sparsely limited. The only potentially suitable accommodation would be a sightseeing area overlooking the intake structure. This potential and any other recreational features which subsequently surface would be explored in the final design stage.

All intake and outlet structures including associated features such as log boom, gate structure, operator's quarters and maintenance quarters would be designed to provide architectural compatibility with the surrounding area.

EFFECTS ON FLOOD DAMAGES

Because of the nature of this structural element, a very high degree of protection can be afforded by the diversion to downstream areas. This degree of protection is dependent upon the diameter of the tunnel (regulates the amount of transfer of floodwaters out of the basin and into Apponaug Cove) and the location of the damage area (the farther downstream the greater the amount of uncontrolled drainage entering the river and the greater the effect of potential hurricane tides). The following table illustrates the relative effectiveness of the various sized diversion tunnels on all downstream zones. The figures represent only residual losses to structures present when the damage survey was completed in 1972 with all prices updated to September 1978 dollars. The figures do not reflect any growth.

		ZONE 4	ZONE 5	ZONE 6	ZONE 7	ZONE 8	TOTALS
21' dia	Benefits	119,560	99,980	32,760	147,650	196,820	$596,770
	Percent Reduction	.59	.82	.58	.60	.48	
27' dia	Benefits	172,790	115,380	36,270	152,910	207,740	$685,080
	Percent Reduction	.97	.94	.65	.62	.51	
30' dia	Benefits	175,560	120,130	36,270	154,760	208,950	$695,670
	Percent Reduction	.98	.98	.65	.63	.51	
33' dia	Benefits	176,490	121,460	36,270	154,950	213,930	$703,100
	Percent Reduction	.99	.99	.65	.63	.52	

Table 4-4 shows the stage reduction in feet for each of the five zones downstream of the diversion of three theoretical flood events, the five percent, one percent and the two-tenths percent. The March 1968 flood event on the Pawtuxet is more frequent than the five percent storm.

TABLE 4-4

STAGE REDUCTIONS FROM VARIOUS
SIZED NATICK DIVERSION TUNNELS
AT SPECIFIC FLOOD EVENTS

	ZONE	21' dia	27' dia	30' dia	33' dia
5% Chance of Occurrence	4	2.9	2.9	2.9	2.9
	5	2.9	2.9	2.9	2.9
	6	1.4	1.4	1.4	1.4
	7	1.4	1.4	1.4	1.4
	8	1.1	1.1	1.1	1.1
1% Chance of Occurrence	4	4.3	4.3	4.3	4.3
	5	4.0	4.0	4.0	4.0
	6	2.4	2.4	2.4	2.4
	7	2.6	2.6	2.6	2.6
	8	1.0	1.0	1.0	1.0
.2% Chance of Occurrence	4	2.8	6.3	6.9	7.4
	5	3.2	7.0	7.2	7.6
	6	3.1	5.2	6.0	6.0
	7	1.6	3.0	3.8	3.8
	8	0.9	1.9	2.6	2.1

ECONOMICS OF THE SINGLE PURPOSE NATICK DIVERSION PLAN
COST AND CHARGES

FIRST COSTS AND PROJECT INVESTMENT

Detailed estimates of the construction and associated costs for the plan are summarized by item category in Table 4-5. Applied unit prices are based on average bid prices for similar work in the geographical area and reflect 30 June 1976 price levels, with totals updated to September 1978. Based on previous experience with similar projects the application of a 20 percent contingency factor on all items, exclusive of rock excavation costs taken 15 percent, was considered to be sufficiently adequate for this type of study. The overhead rates of 5.5 percent each for engineering and design, and for supervision and admnistration are based upon experience, knowledge, and comparison with similar projects and studies within this Division. Costs for lands and damages were derived on Page 4-7.

The project investment is shown below and was determined by applying the Federal interest rate of 6 and 5/8 percent during construction for one-half of the estimated construction period of four years. All costs have been updated to reflect September 1978 price levels.

Project Investment

	Natick Diversion
Project First Cost	57,800,000
Interest During Construction	7,658,500
	65,458,500

ANNUAL CHARGES

The average annual charges shown below are based on a capital recovery factor reflecting an interest rate of 6 and 5/8 percent with amortization over a 100-year life of the project for the Federal investment. Included in the annual charges are allowances for operation and maintenance, major replacements and loss of taxes on lands.

Annual Charges

Interest and Amortization	4,343,000
Operation and Maintenance	113,000
Major Replacements	1,200
Loss of Taxes on Land	800
TOTAL (Rounded)	4,458,000

TABLE 4-5

PROJECT COST OF STRUCTURAL
ELEMENT OF THE
NATICK DIVERSION (30′ DIA.)

	QUANTITY	UNIT COST	TOTAL COST
Preparation of Site	1	L.S.	$ 2,120,000
Stream Control	1	L.S.	2,075,000
Dredging	14,500	11.60	168,200
Earth Exc. (Common)	12,000	4.40	52,800
Rock Ex. (Common)	6,000	16.80	100,800
Rock Exc. (Tunnel & Shaft)	420,000	53.60	22,512,000
Rock Slope Protection	4,400	17.50	77,000
Gravel Bedding	4,000	7.70	30,800
Compacted Gravel Fill	1,500	7.50	11,250
Reinforced Concrete			
1. Diversion Dam	1,700	90.00	153,000
2. Diversion Intake	2,400	192.00	460,800
3. Diversion Outlet	3,800	200.00	760,000
4. Tunnel Lining	72,000	62.00	4,464,000
Shotcrete	13,000	6.30	81,900
Cement	538,000	3.10	1,667,800
Reinforcing Steel	4,548,000	0.50	285,000
Tunnel Bracing & Mine Ties	9,000	0.90	8,100
Water Stops	600	11.60	6,960
Bituminous Conc. Pavement	1,500	4.10	6,150
Cable Guard Rail	500	11.60	5,800
6′ Security C.L. Fence	1,000	8.00	8,000
Two - 8′x8′ Sluice Gates	1	L.S.	57,000
Stop Log Barrier	1	L.S.	5,000
Tunnel Ventilation	1	L.S.	226,000
Landscaping	1	L.S.	28,000
SUBTOTAL			$37,645,000
Contingencies (17.2%± Composite)			6,500,000
SUBTOTAL			$44,145,000
Engineering & Design (5.5%±)			2,242,000
Supervison & Administration (5.5%±)			2,242,000
TOTAL CONSTRUCTION COSTS			$48,629,000
Lands and Improvements (Fee/Permanent Easements)			98,200
Temporary Construction Easements			67,500
Acquisition Costs			86,000
Relocation Assistance Costs			13,800
Contingencies			54,800
TOTAL LANDS & DAMAGES			320,000
TOTAL COST			$48,949,000
updated to September 1978 dollars			$57,270,330

BASIC BENEFITS

Natick Diversion provides flood protection to all downstream zones in varying degrees. With the basin experiencing a rapid growth both within the flood plain and outside of it, flood discharge frequencies, as explained in Appendix 1, are expected to increase 10 percent between the initiation of the study (1972) and 1990, and another 10 percent between 1990 and 2020. All damages and benefits, updated to September 1978 price levels, reflect the level of development present in the watershed for mid-1972. An example of the effect of urbanization on existing damages is shown on Plate 4-2.

Flood damage reduction benefits were derived as the difference between flood damages without the project in each reach of river to be affected and those that would remain with the project in operation.

At the time of the original preparation of this section, 1985 was taken as the base year for benefit analysis. Benefits were computed for 1985, 1990 and 2020 reflecting the changes in the loss potential to be expected with time. Values for 1990 and 2020 were brought back to current values by present worth methods using an interest rate of 6 and 5/8 percent.

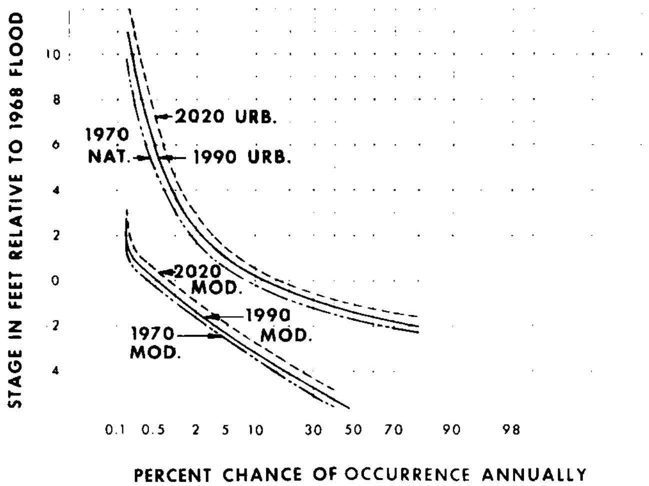
Table 4-6 shows the average annual damages, annual benefits to the Natick Diversion and the annual losses remaining with project implementation for each of the five main impacted zones. All urbanization effects are included for the 1972 scale of development.

FUTURE GROWTH BEFORE PROJECT COMPLETION (1972-1985)

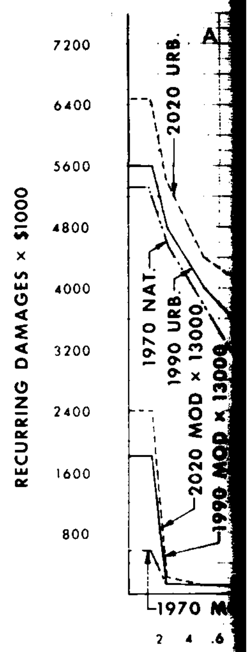
From the date of the initial damage survey (1972) to original preparation of the initial draft survey report (Oct 1976) numerous new structures had been built in the flood plain. Many have first floor elevations below the hundred year flood limits. During that referenced period including the interval up to the present, the growth rate has exceeded that cited in Appendix 1.

The losses to these structures, those being built in the flood plains today, as well as those contemplated in the future were derived using the methodology explained in Appendix 7, "Economics." However, because of the greater protected area afforded by the diversion, considerable more effort went into determining the appropriate benefits and losses.

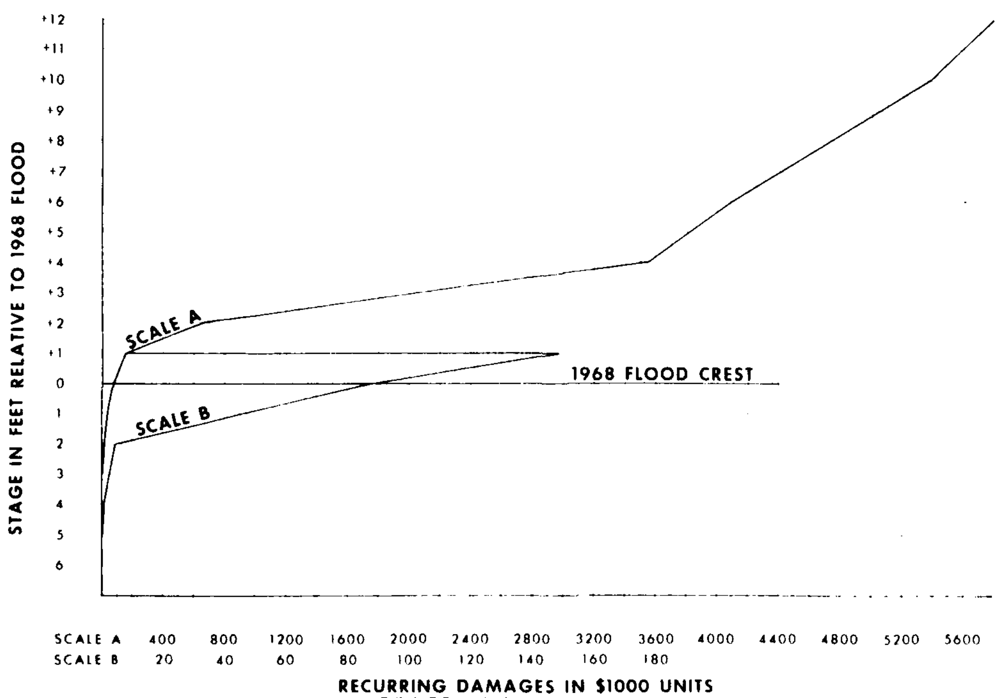
It then became necessary to determine where the growth could occur for each of the three major land use categories (residential, commercial, industrial). Table 4-7 represents the available land within the mainstem Pawtuxet River. It shows that there are only 53 acres of



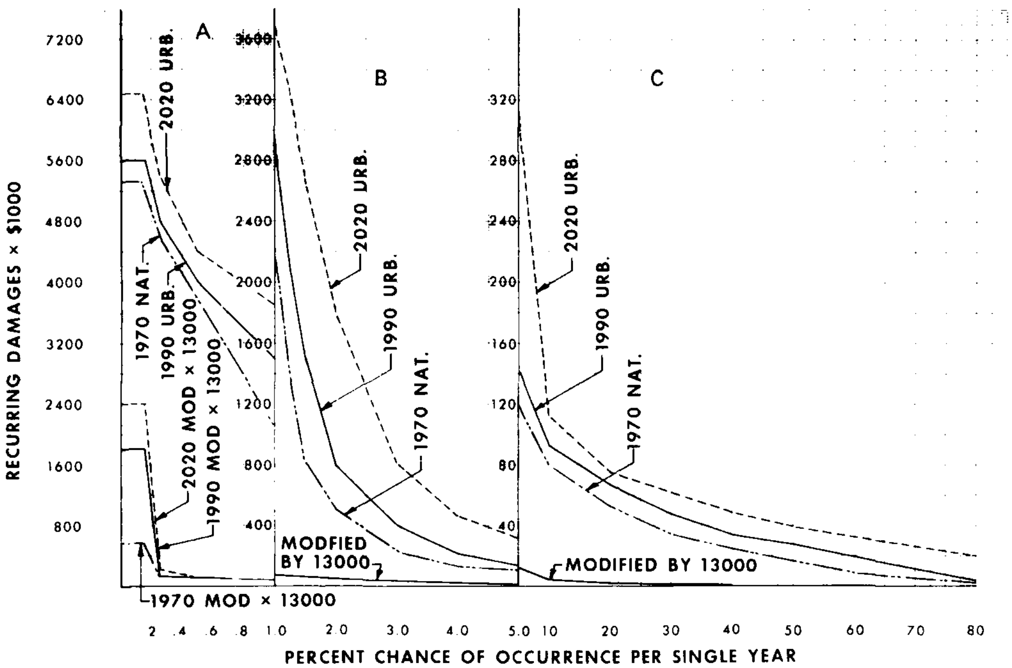
STAGE - FREQUENCY CURVE
(INDEX STATION-RIVER SECTION 340+00)



2020 URBAN
1990 URBAN
NATURAL
2020 MOD X 1300
1990 MOD X 1300
1970 MOD X 1300



STAGE DAMAGE CURVE
1972 STUDY
1972 PRICE LEVEL



DAMAGE - FREQUENCY CURVE

NOTE: ACTUAL AREAS FOR ALL CONDITIONS HAVE BEEN CALCULATED. THE MODIFIED CURVES, UNLESS OTHERWISE SHOWN, INDICATE 2020 URBANIZATION AS MODIFIED BY A 13000 CES DIVERSION.

	RANGE A 1 sq.in.= $3200			RANGE B 1 sq.in.= $4000			RANGE C 1 sq.in.= $4000			AVERAGE ANNUAL	
	AREA	LOSS	BEN	AREA	LOSS	BEN.	AREA	LOSS	BEN	LOSSES	BENEFITS
2020 URBAN	14 92	47,744		12.33	49,320		11.37	45,480		142,544	
1990 URBAN	13 23	42,336		6 96	27,840		8.00	32,000		102,176	
NATURAL	11 94	38,208		4.47	17,875		5.98	23,920		80,003	
2020 MOD X 13000	1 81	5,792	41,952	35	1,400	47,920	.28	1,120	44,360	8,312	134,232
1990 MOD X 13000	1 38	4,416	37,920	19	750	27,090	.14	540	31,460	5,706	96,470
1970 MOD X 13000	53	1,696	36,512	09	375	17,500	07	280	23,640	2,351	77,652

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

DAMAGE-FREQUENCY-STAGE RELATIONSHIPS

URBANIZATION EFFECTS - ZONE #5

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION CORPS OF ENGINEERS
WALTHAM, MASS

TABLE 4-6

AVERAGE ANNUAL LOSSES
AND BENEFITS

1972 Scale of Development - September 1978 Price Level

Location	Total Annual Damages	Benefits to 30 Ft. Diversion	Residual Losses
Zone 4	297,000	290,600	6,400
Zone 5	183,500	171,800	11,700
Zone 6	98,500	66,300	32,200
Zone 7	469,000	302,000	167,000
Zone 8	564,400	300,400	264,000
TOTAL	$ 1,612,400	$ 1,131,100	$ 481,300

TABLE 4-7

AFFECTED AREA LAND USE[1]
1970
(Acres)

	TOTAL LAND			FLOOD PLAIN[2]			
	Current Use	Vacant	Total	Current Use	Available Vacant	Flood-way Vacant	Total
Residential	18,029	52,676	70,705	369	253	30	652
Commercial	1,830	1,240	3,070	203	29	24	256
Industrial	2,042	2,754	4,796	260	474	131	865
Recreation	178	115	293	--	--	--	--
Agriculture	587	--	587	--	--	--	--
Public	3,154	--	3,154	167	3	--	170
Airport	975	--	975	--	--	--	--
Open Space	100	--	100	3	--	--	3
	26,895	56,785	83,680	1,002	759	185	1,946

1) Affected area includes Cranston, Warwick, West Warwick and Coventry.

2) Includes area up to the SPF along main stem Pawtuxet River only.

commercial land available for development, 24 of which are located in the floodway. At the calculated growth rate, this land, exclusive of the flooding will be saturated within 10 years. From the land use analyses, 75 percent of the commercial growth would occur in Zone 4 and the remainder in Zone 8.

In this interval, industrial growth will consume a total of only 39 acres of vacant land. Industrial growth is projected in the following areas at these rates.

Zone 5	33%
Zone 4	23%
Zone 6	22%
Zone 8	22%

The losses and benefits for this period are shown on Table 4-8.

Saturation will not occur.

FUTURE GROWTH OVER PROJECT LIFE (1985-2085)

This phase of growth would occur after the selected plan is operational. Growth will continue at the pre-project growth rate of 3.0 acres per year or industrial zoned land. Growth will not be determined for residential use as existing multi-family zoned land is rather limited. Commercial vacant land is non-existent. Rezoning of the vacant industrial land or single family residential land will not be assumed, although this practice has occurred within the study area. At the base year of the project, as originally conceived was 1985, about 566 acres of industrial land should be vacant within the standard project flood confines. Significant vacant land is available in Zone 5, with lesser amounts in Zones 4 and 6. Little vacant land is available within the Cranston portions of Zones 7 and 8.

Within the Warwick industrial park about 50 acres of prime industrial land would be vacant by the base year. (Ten additional acres of land will have been utilized in the 1972 to 1985 growth period.) Several of the existing firms are now prohibited from enlarging the facilities because of existing constraints on expansion within the fifty-year flood plain. Because of the desirability of locating within the Warwick Industrial Park (sewered area, adjacent to good connecting highway system, availability of public water supply and public transportation) all new growth will occur within this area until the existing vacant land becomes saturated as a result of the protection afforded it by the diversion.

All the industrial growth has been projected to occur within the Warwick Industrial Park for the period up to 1995. The remainder of the growth, from 1995 to 2085, is expected to occur in Zones 4, 5, and 6. It has

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TABLE 4-8

1972 TO 1985 FUTURE GROWTH
BEFORE PROJECT COMPLETION

Type & Location	Total Annual Damages	Benefits to 30 ft Diversion	Residual Losses
Industrial			
Zone 4	$ 66,830	$ 59,560	$ 7,270
Zone 5	105,810	103,380	2,440
Zone 6	67,100	50,630	16,480
Zone 8	59,060	33,150	25,900
Sub-Total	$ 298,800	$ 246,720	$ 52,090
Commercial			
Zone 4	$ 143,550	$ 132,860	$ 10,690
Zone 8	39,650	25,030	14,630
Sub-Total	$ 183,200	$ 157,890	$ 25,320
Residential			
Zone 4	$ 108,500	$ 98,140	$ 10,360
TOTALS	$ 590,500	$ 502,750	$ 87,770

been estimated that 50 percent of the growth is expected to be in Zone 5, and the remainder equally distributed between 4 and 6. New dummy unit stage-damage curves were determined for these three zones. Damages, benefits and residual losses were then calculated for this phase. Increases in losses (benefits) were included for the changes due to urbanization.

Plate 4-3 shows the damage, frequency and stage relationships for Zone 5 and Table 4-9 summarizes the 1985 to 2085 allowable growth, both under the "with the project conditions." Table 4-9 has been updated to reflect the September 1978 price levels.

LOCATION BENEFITS

Along the lower 10 miles of the Pawtuxet River there are about 385 acres of floodway lands where development wuld not be permitted under the National Flood Insurance Act (NFIA). These areas have not as yet been officially delineated by the Federal Insurance Administration, but are expected to be in the near future. The diversion would virtually eliminate the floodway. Much of this land could now be developed. About half of the 385 acres of land is zoned industrial, with the remaining portion unsuitable for most uses as the areas are either State or local conservation land or limited access areas created by the interstate system. The final choice of values for benefits in this category were equated to the difference in the market value of the flood plain land with and without flood protection. A ten year growth period was employed for the land to reach its peak use value. Consultation with local real estate brokers and knowledge of past sales within the area by the Real Estate personnel of this Division established the present value of the floodway land and the value of comparable land outside the flood plain.

The following tabulation represents area, percent developable, land use classification, value of land with and without the project, and net worth of the existing vacant floodway.

FLOODWAY AREA

Area (Acres)	Percent Developable	Use	Future Value $/S.F.	Existing Value $/S.F.	Net Worth x $1,000
180	75	Industrial	$1.50	$.10	$8,233
13	100	Industrial	$2.00	$.10	$1,076
2	100	Commercial	$1.50	$.10	$ 122
					$9,431

TABLE 4-9

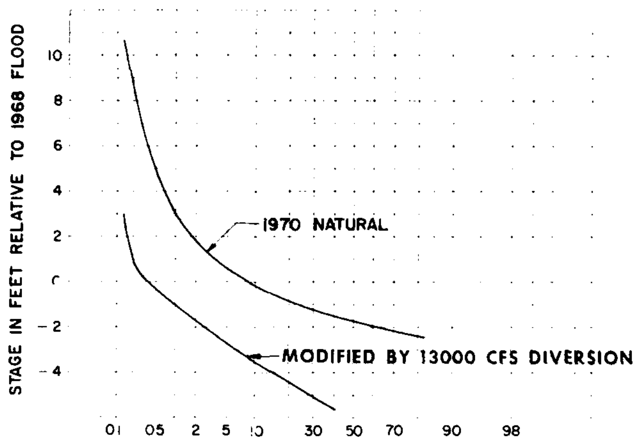
NATICK DIVERSION

FUTURE INDUSTRIAL LOSSES AND BENEFITS

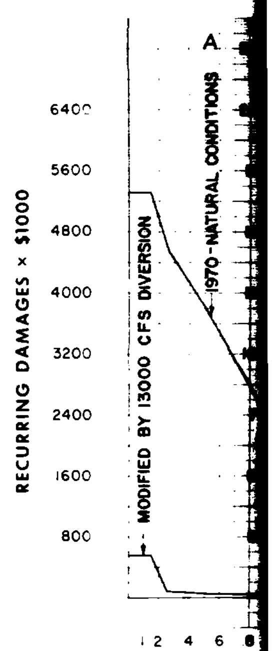
1985 - 2085

September 1978 Price Level

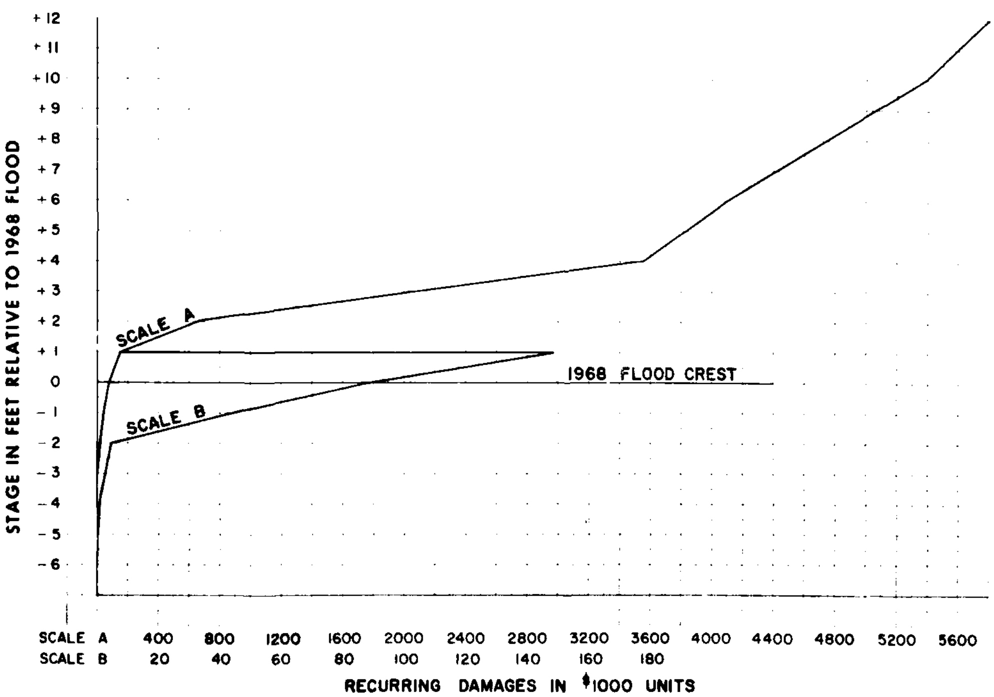
Location	Total Annual Damages	Benefits to 30 ft Diversion	Residual Losses
Zone 4	94,100	85,790	8,320
Zone 5	354,450	335,320	19,140
Zone 6	233,500	167,400	66,100
Zone 7	0	0	0
Zone 8	961,950	516,130	445,820
TOTALS	$1,644,000	$1,104,640	$539,380



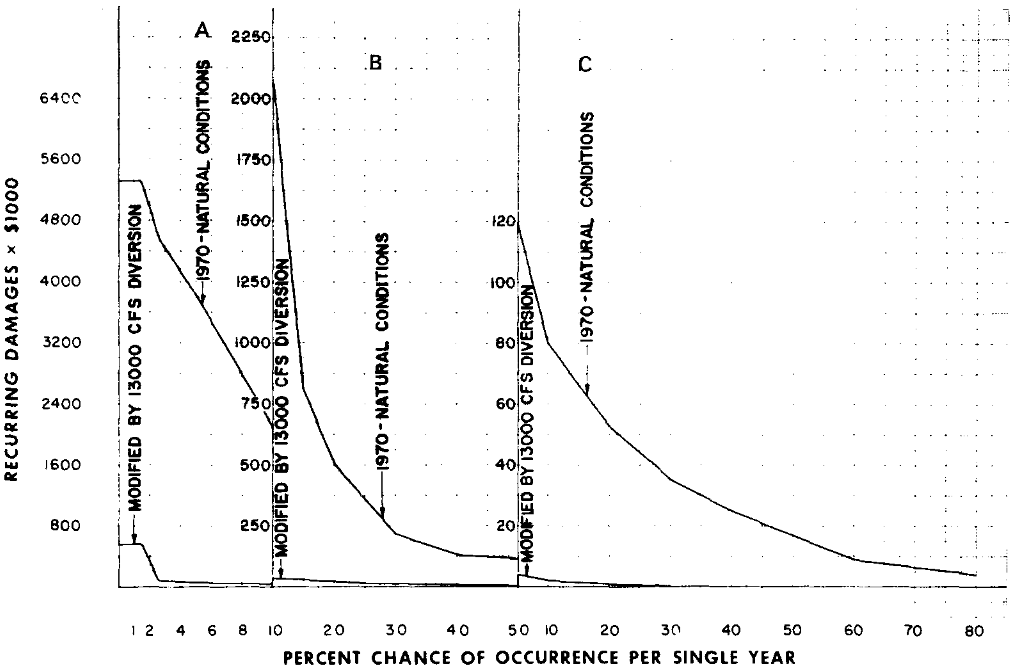
STAGE-FREQUENCY CURVE
NATURAL CONDITIONS
(INDEX STATION-RIVER SECTION 340+00)



NATURAL	
× 13,000 DIV.	



STAGE - DAMAGE CURVE
1972 STUDY
1972 PRICE LEVEL



DAMAGE - FREQUENCY CURVE

1972 STUDY
1972 PRICE LEVEL
FOR 1970 HYDROLOGIC CONDITIONS

	RANGE A 1 sq.in.= $3200			RANGE B 1 sq.in.= $2500			RANGE C 1 sq.in.= $2000			AVERAGE ANNUAL	
	AREA	LOSS	BEN.	AREA	LOSS	BEN.	AREA	LOSS	BEN.	LOSSES	BENEFITS
NATURAL	11.94	38,208		7.15	17,875		11.96	23,920		80,003	
× 13,000 DIV	.53	1,696	36,512	.15	375	17,500	.14	280	23,640	2351	77,652

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND
DAMAGE-FREQUENCY-STAGE RELATIONSHIPS
BASIC BENEFITS - ZONE #5

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS

PLATE 4-3

This is equivalent to an average annual benefit of $680,000 utilizing an eight percent rate of return.

Of the three techniques mentioned in ER 1105-2-351 for measuring so called "Location Benefits", the "change in the market value of land" is selected for final calculations as it is the most quantifiable and factually supported method at the field level. In complex basin flood plain situations such as in this study area, reliable information on economic gains to activities using the flood plain only with protection is extremely difficult to obtain and the degree of confidence in making judgements as to threshold levels is questionable.

AREA REDEVELOPMENT BENEFITS

In labor market areas which have been designated as Redevelopment Areas, Senate Document No. 97 of the 87th Congress directs that the project benefits shall be considered to be increased by the value of the labor and other resources required for project construction and expected to be used in project operation, project maintenance, and additional area employment during the construction of the project. Otherwise, such labor and resources would not be utilized or under-utilized. The Pawtuxet River Basin lies in the providence-Pawtucket-Warwick SMSA, which is designated as a Title IV Redevelopment Area under P.L. 89-136 by the Economic Development Administration. In April 1976, the unemployment rate for this SMSA was 10.5 percent.

The records of this office indicate that in the average civil works project, the labor cost generally approximates 27 percent of total construction costs. However, due to the nature of this work, the labor component for this project has been estimated at 30 percent. As the construction cost of the project is currently estimated at $57,800,000 at September 1978 price levels, labor's share amounts to about $17,340,000.

It is estimated that 80 percent of the laborers will be locally hired for this project. While not all of this labor will come from the rolls of the unemployed, the jobs that they leave will be filled by either the unemployed, or the underemployed; thus 80 percent is used. The above process is shown on Table 4-10.

Benefits are not considered for labor engaged in maintenance and operation of the project after construction as the need is small and the work, associated with the Warwick-Elmwood Avenue local protective works portion, will be handled by the regular public work force of the community.

TABLE 4-10

AREA REDEVELOPMENT BENEFITS

NATICK DIVERSION:

TOTAL CONSTRUCTION COST	$ 56,897,000

YEARLY FUNDING - 4 Years for Construction

1st Year	.............$ 8,775,000
2nd Year	.............$20,475,000
3rd Year	.............$17,550,000
4th Year	.............$10,097,000

PRESENT WORTH VALUE

1st Year:	.93786 x $8,775,000 x .30	=	$ 2,468,900
2nd Year:	.87969 x 20,475,000 x .30	=	$ 5,403,500
3rd Year:	.82494 x 17,550,000 x .30	=	$ 4,343,300
4th Year:	.77368 x 10,097,000 x .30	=	$ 2,343,600
			$ 14,559,300

ANNUALIZING

80% Local Hire x $14,559,300	=	$ 11,647,440
		x .06635
		$ 772,800

BENEFITS TO MUNICIPAL SEWAGE TREATMENT FACILITIES

There are three municipal sewage treatment facilities located downstream of the Natick Diversion that would receive flood stage reductions. Two of these facilities (at Warwick and at West Warwick) have parts of their treatment system below the current 25-year flood with the remaining portions of the Cranston facility located at or above the current 100-year flood level. As the main structural components of the Warwick and West Warwick facilities are below the existing hundred year level, significant damages would result at either the 25 or 100-year flood level for both facilities. As expansion of these facilities is planned in the future, they are required to follow EPA technical bulletin 430-99-74-001 "Design Criteria for Mechanical, Electric and Fluid System and Component Reliability".

This bulletin states that the treatment works' structures including electrical and mechanical equipments shall be protected from physical damage by the future one hundred year flood. In addition, the treatment works shall remain fully operational during the twenty-five-year flood if practicable. As the diversion will reduce flood stages so that minimal damages result at the hundred-year flood and the plants remain completely operative during the twenty-five-year event, a benefit can be credited for this reduction. In accordance with directives, the benefit would be equalled to the least alternative cost of protection for either the 25-year complete operational cycle or the 100-year structural protection. For both affected treatment facilities, the least alternative cost of protection consists of building walls and dikes to the 100-year level of protection as tabulated in Table 4-11. As evaluated by this office, floodproofing of these structures at a 100-year level proved to be far more expensive than the walls and dikes and was obviated as a viable measure.

SENSITIVITY ANALYSIS OF URBANIZATION AND GROWTH

As the area is rapidly intensifying in activity with a large portion within the flood plain, a combination of both urbanization and growth conditions have resulted in significant benefits. There are sufficient so as to allow the project to have a favorable benefit to cost ratio. Although not required, a sensitivity analysis of the urbanization effects and projected growth were evaluated. Five varyng conditions were analyzed: no future urbanization and no future growth; one half the projected growth. The results of this analysis are presented in Table 4-12 which indicates that without the projected growth rates and urbanization conditions, the selected plan would not be justified.

By the addition of some of the previously excluded benefits, the selected plan would be justified at the one half urbanization - full growth condition, or full urbanization and half the projected growth.

TABLE 4-11

LEAST ALTERNATIVE COSTS FOR
FLOOD PROTECTION OF MUNICIPAL
SEWAGE TREATMENT FACILITIES

100-Year Level of Protection, Including Freeboard

PROJECT INVESTMENTS

West Warwick Construction Cost		$ 892,000
Warwick Construction Cost		1,012,000
		$1,905,000
Interest During Construction 2 Years x 1/2 x .06625 x $1,905,000	=	316,000
TOTAL PROJECT INVESTMENTS		$2,221,000

ANNUAL CHARGES

Interest and Amortization:		
100-year life @ 6 and 5/8 percent .06635 x $2,221,000	=	$ 147,000
Operation and Maintenance		7,000
AVERAGE ANNUAL COST AND BENEFITS (FOR PROTECTION TO MUNICIPAL SEWAGE TREATMENT FACILITIES)	=	$ 154,000

TABLE 4-12

SENSITIVITY ANALYSIS OF URBANIZATION AND GROWTH

Type of Benefit	No Urbanization - No Future Growth	50% Urbanization No Future Growth	50% Urbanization 50% Growth	50% Urbanization 100% Growth	100% Urbanization 50% Growth
Basic Flood Control	893,600	1,104,700	1,104,700	1,104,700	1,406,500
1972-1976 Growth	121,500	144,300	144,300	144,300	167,200
1976-1985 Growth	0	0	146,900	293,800	214,100
1985-2035 Growth	0	0	635,000	1,222,800	926,200
Location	853,200	853,200	835,200	853,200	853,200
Area Redevelopment	879,400	879,400	879,400	879,400	879,400
Sewage Treatment Plant	130,900	130,900	130,900	130,000	130,000
TOTALS	2,878,600	3,112,500	3,894,800	4,628,200	4,576,600

In addition, the substitution of a reduced tunnel size would reduce construction costs and result in a justified project for a limited growth condition.

The plan is sensitive to the future conditions within the basin. Based upon the rapid growth within the past decade, the projected growth and job opportunities, the lack of vacant industrial land within the region and the high degree of security that the flood control projects uld afford, all prior urbanization and growth rates were conservatively estimated. The minimum level of growth and urbanization conditions thought to be representative of the future were evaluated previously. The results of that analysis resulted in a justified selected plan.

FLOOD CONTROL BENEFITS EXCLUDED FROM ECONOMIC ANALYSIS

Other vacant non-floodway land below the 100-year flood plain will also reap significant benefits due to the diversion and local protection project. The provisions of the National Flood Insurance Act of 1973 were fully compiled with in projecting growth in the flood plain. Urbanization was not projected in the estimated 100-year floodway. All future development in the estimated 100-year floodway fringe was assumed to be floodproofed against the 100-year flood. The most economical and feasible method of floodproofing in this area would be to build structures on fill. With the Natick Diversion, there are approximately 770 acres of floodway fringe that are no longer subject to flooding at the 100-year level. The reductions in water surface due to this project are shown on Plate 2 of the hydrology report.

Of this area, about 400 acres are vacant. The cost to fill this area to the 100-year flood level would be about $6 million or $380,800 annually. With flood control improvements in place, this filling would be unnecessary. In addition, the remaining land still subject to flooding at the new 100-year flood level, in theory requires even less fill which would result in even greater benefits.

An additional item which was not included in the benefit anaysis is the assumption that portions of the vacant industrial land would be rezoned as commercial. There is a large demand for this category of land use, and significant rezoning of land has occurred in the past. No commercial growth was assumed past 1982. By that date, the existing land zoned as commercial will have been saturated. During the growth period, from 1972 to 2085, about 200 acres of industrial land will be used. As there are currently about 600 acres so zoned, about 400 acres should be vacant. A significant portion of this land would probably be rezoned, or be used for industry at a higher growth rate than used during the conduct of this study, which would result in far greater economic benefits.

Other items not included as benefits involve the savings in premium cost under the National Flood Insurance Program for covered structures, benefits to the interstate transportation system afforded as I-95 would no longer be subject to flooding, flood fighting costs, the increased damages to be experienced inside of existing, or future structures due to the addition of more sophisticated, and more expensive equipment, and the increased value of the utilized flood fringe land now flood-free. All flood-free structures would now be worth more, and thus would be attributable to the selected plan.

Another major benefit not claimed would be the theoretical savings to homeowners and industry in the cost of providing floodproofing costs. From Table III-1 this cost for the 100-year flood event is about $57,000,000 to the 1972 existing structures. With this diversion scheme many of these would receive a high degree of protection. However, there still would be the need to floodproof over 200 structures.

EFFECT ON THE ENVIRONMENT

Potential Impacts in Apponaug Cove and Greenwich Bay. Diversion of freshwater into Apponaug Cove and Greenwich Bay could have a significant impact on the environment. A sampling program for the Pawtuxet River was initiated by the Corps of Engineers through the auspices of the Federal Environmental Protection Agency (EPA) to determine existing concentrations of various water quality parameters.

It was envisioned that during this sampling period, some high flows would be encountered that would be representative of flood conditions. However, the maximum experienced flows for the sampling dates were less than 700 cfs. For the diversion to be operative, a flow in excess of 1,800 cfs would be required. From an analysis of these current water quality data, only the coliform group of micro-organisms presents a source of public health problem. However, due to the diversion of the freshwater (Pawtuxet River) into the saline environment (Apponaug Cove and Greenwich Bay) the overall salinities in the Cove and Bay will be temporarily reduced. Although not a public health problem, it will induce physiological stress on the marine flora and fauna present in Apponaug Cove and Greenwich Bay.

The total coliform counts on the Pawtuxet River at the Natick Dam sampling station varied from a minimum of 2,400 groups per 100 milliliter (ml) to over 240,000. The total coliform value of 13,000 groups per 100 ml is the geometric mean for the sampling period (September 1975-June 1976). As some of the sources of the coliform groups are known, some of these discharges may be tied into the West Warwick sewage treatment facility in the near future. It can be assumed

that most of these effluents will have a significantly less pollution load by the time the project is operational as the existing discharges would be in violation of Public Law 92-500, Federal Water Pollution Control Act, as amended. It is envisioned that by the time the diversion would be operative, an average total coliform group value at normal flows would probably be less than 1,000 groups per 100 ml. This would be further reduced when the river reached flood stage. In addition, it has been reported in technical literature[1] that a significant reduction in coliform counts occurs due to the toxic effect of saline water on coliform bacteria. The reduction is dependent upon the final percent salinity of the aggregate mixture, and the exposure time.

A mathematical model study was then employed to evaluate, as well as to predict, the anticipated impact on Apponaug Cove and Greenwich Bay due to the operation of the diversion. The impacts of the diversion were modeled for three tidal conditions, namely; spring tides, neap tides, and a specified storm tide condition during normal tide. The storm tide was modeled by adding a constant surge of 8.6 feet to the normal tide cycle. Flow rates consisted of one constant rate of diversion equal, to 200 cfs, and two time variable flow rates having maximum values of 2,300 cfs and 14,500 cfs.

The mathematical model used for the analysis of the diversion was a modification to an existing model of Narragansett Bay. The model was modified to apply only to Greenwich Bay and to include the diversion of the Pawtuxet River into Apponaug Cove. The dilution of the input source, the Pawtuxet River, and the addition of excess concentrations of the parameter under investigation, are predicted by using a far field advection-diffusion model in which concentration distributions are determined by advection (currents), turbulent diffusion, and natural decay processes. This Effluent Dispersion Model is a two dimensional computer model which predicts the concentration of the discharged material over the study area. Impacts to the far-field model include the spatially and temporarily varying advective currents. To obtain these currents, a circulation model was employed.

The circulation model predicted the currents throughout a vertically well-mixed two dimensional embayment from a knowledge of the tide heights and/or currents at the open boundaries of the embayment. Once calibrated, the model was used to predict the circulation patterns for the three tide conditions.

[1] Hanes, N. Bruce and Fragal, Robert "Effect of Seawater Concentration on Survival of Indicator Bacteria," Journal of the Water Pollution Control Federation, January 1967.

The computerized Effluent Dispersion Model estimated the changes to the present water quality of Greenwich Bay due to the influx of freshwater diverted from the Pawtuxet River. The model predicted the vertically averaged excess concentrations of coliforms, biochemical oxygen demand, temperature, dissolved oxygen and suspended solids throughout a well-mixed horizontal two-dimensional plane. The ambient transportation process of advection and turbulent diffusion were included in the model along with the internal decay mechanisms. The model translated the time varying diversion discharge into time varying excess constituent concentration and dilution patterns throughout the study area.

200 CFS DIVERSION RATE - Utilizing the existing water quality data as the input for the model, the constant flow rate of 200 cfs was analyzed. At the peak impact time, when the volume of saltwater in Apponaug Cove Greenwich Bay was at a minimum salinities were reduced to 75 percent of ambient throughout Apponaug Cove and a small portion of Greenwich Bay. The effects of salinity change to marine life at this rate were essentially negligible and the affected area was limited to Apponaug Cove. Excess coliforms introduced to the Cove Bay area were also analyzed at the critical period. The results indicated that 5 percent of Greenwich Bay would be exposed to additional coliforms due to the diversion for a period of about one day, and at peak impact it would have a concentration of about 5 percent of the input total coliform bacteria. Utilizing existing water quality data this would be equivalent to a maximum additional concentration of [illegible] groups per ml. However, assuming future conditions, the maximum [illegible] concentration would only be about 50 groups per 100 ml. For a [illegible] tide or constant tide surge conditions, the affected area would be limited to Apponaug Cove.

2300 CFS DIVERSION RATE - Next, salinities and the coliform group for the 2,300 diversion rate were analyzed. For the salinities, the greatest impact is experienced during spring tide. The significant area in terms of effect upon marine species lies within the 50 percent change contour. In this range, the salinities will vary between 10 to 15 parts per thousand (normal concentration of Greenwich Bay varies between 20 to 33 parts per thousand). A reduction in salinity below a value of 10 parts per thousand would physiologically stress and destroy most early life stages of marine life. This would result in the loss of the year class for species for about 10 percent of the Bay, and all of Apponaug Cove. After the diversion ceased to operate, the return time to 70 to 90 percent of ambient salinities throughout Greenwich Bay would take two tide cycles or about 26 hours. At neap tide, the affected area of the 50 percent contour is similar, and at the constant storm surge, the affected area is less than 10 percent of Greenwich Bay.

At the 2,300 cfs diversion rate and at peak impact, the area within the 2 percent contour for coliforms would consist of about 50 percent of Greenwich Bay. The duration of exposure for this area to increased coliform bacteria due to the diversion would be about 40 hours. Under existing water quality conditions, the 2 percent of input coliform bacteria would be equivalent to the presence of an additional 260 groups per 100 ml. With the anticipated improvements in the sewerage systems upstream of the diversion intake, this would amount to only about 20 groups per 100 ml. in the time frame the diversion would be operative.

14,500 CFS DIVERSION RATE — The final series of analyses included the diversion flow rate of up to 14,500 cfs into Apponaug Cove and Greenwich Bay. At this rate the salinities in the Bay and Cove are significantly affected. At the peak impact, which occurs during neap tide conditions, about 70 percent of Greenwich Bay would have reduced salinities causing mortality for some adult species, and eliminating the early life stages for all marine species residing in the Cove and this portion of the Bay.

With the diversion rate, excess coliforms would be present in all of Greenwich Bay for all tide conditions.

Sensitivity of the Mathematical Model and Biological Analysis The data derived from the model analyses of the various diversion flows represents a worse possible situation. The model assumes single layer mixing without stratification. This would differ from a real life estuarine situation in which saltwater would under lie the freshwater because of its greater density.

Estuarine organisms can tolerate or avoid stress conditions created by the reduced salinities. For example, clams such as the quahog or mussel, tightly close their bivalves to avoid a noxious environment. Bottom and mud dwelling species may not experience the full effect of salinity reduction since sediment salinities can remain high while water salinities can vary drastically. Polychaete worms and mud dwellers can burrow or secrete slimes to protect sensitive body surfaces. Some organisms can also osmotically regulate their internal salt balance while other animals (conformers) passively equilibrate salt balance. The survival success afforded by these mechanisms both physiological and mechanical is dependent upon the amount and duration of exposure to the reduced salinities. Other marine species, such as the winter flounder would probably escape harm by swimming out of the stress areas. Considering this information, it is predicted that the major impact from salinity reduction will adversely affect egg and larval stages of marine organisms rather than adult forms.

Summary of Impacts in Apponaug Cove and Greenwich Bay

Due to the sensitivity of the mathematical model and the subsequent biological analyses, actual numbers of species adversely affected by salinity changes due to the diversion cannot be determined.

The total coliform group of bacteria does not stress marine species as do changes in salinity. Rather, it poses a potential public health problem. When the waters of any marine environment in Rhode Island exceed a most probable number (MPN) of 70, the area is closed to shellfishing. Since portions of Greenwich Bay are utilized for shellfishing, the operation of the diversion could result in temporary closure of some of these areas. The critical parameter would be the concentration of the total coliform group of bacteria present in the diverted floodwaters of the Pawtuxet River. The time required from the onset of changes in coliform concentrations to complete recovery at selected areas is summarized as follows:

Area Closed	DIVERSION EVENT (in days) 200 cfs	2,300 cfs	14,500 cfs
Apponaug Cove	2	7	6
5 Percent of Bay	1	6	[illegible]
15 Percent of Bay	0	4	5
50 Percent of Bay	0	1	4
90 Percent of Bay	0	0	3

Actual concentrations of coliforms are not used. When improvements, if any, are made to the water quality conditions upstream of the Natick Diversion intake works, these conditions will be further reduced.

At present, Apponaug Cove is closed to all shellfishing activities. In terms of potential impact to the economy of the area, as the 2,300 cfs diversion is an event expected to occur on the average of once every 15 years, and the 14,500 cfs diversion exceeds a hundred year diversion rate, a small portion of Greenwich Bay would be expected to be closed for only 4 days every 15 years due to operation of the diversion.

Freshwater Flora and Fauna - As the amount of above-ground construction at the site of the diversion intake will be confined to about one acre of land in the vicinity of existing Natick Pond Dam, the impact, if any, upon any freshwater community would be negligible.

Water Pollution - With the construction of the Natick Diversion, there will be no appreciable day-to-day improvements in the overall water quality of the lower Pawtuxet River. However, due to the reductions in stages of flood events, the three municipal treatment facilities will be

able to remain operative during a hundred year flood, and only receive minor damage at a standard project flood level. At a yearly type diversion event, the reduction in stages will be such that floodwaters will not inundate the sludge disposal areas of any of the three treatment facilities.

Noise and Air Pollution During the construction phase of the Natick Diversion, significant adverse impacts would be likely to occur. A prime source of noise will be the large ten wheel dump trucks hauling rock spoil and other material away from the tunnel to disposal areas. The key impacted areas will be along U.S. 1 in Apponaug, a section of Warwick; Providence Avenue (RI 33) in Warwick and West Warwick; Bald Hill Road (RI 2), Elmwood Avenue (U.S. 1) and Warwick Avenue (RI 117) in Warwick. Additional noise will be created at the disposal sites. There would be about 20 truckloads of rock spoil per day removed from the tunnel during the four-year construction period. This would amount to about two trucks per hour. All of the previously mentioned roads are heavily travelled regularly by trucks of this type and in far greater numbers.

Noise associated with the tunnel construction will be minimal. In addition to the truck traffic previously mentioned, other sources of noise would consist of the rock hoisting equipment at the outlet structure (an area where the nearest inhabitated structure is within 300 to 400 feet), and the noise during construction of the above-ground portions of the intake and outlet structures. Although blasting will be used extensively during construction of the tunnel and shafts, construction methods including blasting techniques will not be of the magnitude that would adversely affect surtace or near-surface, in-ground improvement. The size of charges will be so designed so as not to create any shock waves or excessive noise, therefore, the impact due to the blasting will be nonexistent.

Throughout the duration of the construction activities, the air quality will be degraded. This will be attributable to fine particulate matter given off by the rock spoil disposal and hoisting equipment, the hauling of the spoil, and the disposal at either the local protection project sites or other selected spoil areas. Other factors which would also degrade the air quality would be the diesel exhaust emissions from the earth moving equipment. All of these conditions will be temporary in nature due to the construction activities.

Land Use - As the selected plan will provide a high degree of flood protection for the land downstream of the intake structure, more land will become available for either new development or intensification of present usage. Consequently, this will increase the value of the land

and make it more highly desirable for development. The new growth anticipated as a result of the implementation of the selected plan should conform with the zoning regulations of each of the municipalities, and as such, would probably not be considered adverse with respect to local plans.

At the diversion intake and outlet works, the land acquisition program is minimal with negligible impact upon growth. The intake structure involves only 1.80 acres of land to be purchased in fee simple including the acquisition of one residential structure. Although about one acre of this land is industrially zoned, it is currently vacant and partially used for storing of junk vehicles and related parts, and located within the floodway fringe area. The remaining 0.80 acreage consists mostly of vacant residential lots on steeply sloped land not too conducive to development.

As the outlet works will be substantially located within the limits of the mean high water marks, an area under State jurisdictioin as defined by law, land taking will be very minimal. It will include about one acre of industrially zoned land inclusive of a segment of an existing access road, a fisherman's shack and a wood timber bulkhead sea wall. As the current use of required land, which lies in a hurricane danger zone, is governed by rules and regulations of the local government and also regulated by the State Coastal Resources Management Council for environmental protection which require buildings to be built above 14 feet, msl, land taking will have negligible impact upon potential growth development of the area.

As the tunnel will be driven through bedrock at considerable depths below ground surface, land taking in fee simple is unnecessary. However, subsurface easements on 50 parcels of land including above-ground restrictions will be required. These restrictions would include future construction programs along the tunnel alignment that could hinder or potentially damage the tunnel. For example, drilling a deep well to a water bearing strata would be prohibitive, but construction of above-ground buildings including driven piles could be granted with Federal permission.

<u>Aesthetic Impacts</u> The Natick Diversion would involve construction of a new dam approximately 200 feet downstream from existing Natick Pond Dam. The river section in this reach, presently natural streambed between fairly steep banks, would be unchanged except during flood events. During periods of high flows the water level would be regulated so as to allow excess Pawtuxet flood waters to pass over and into the inlet structure into the tunnel, then be on route to Apponaug Cove.

Under normal flow conditions, the top of the new (regulating) dam would be exposed by about 20 feet above the normal river level and the inlet structure by about 8 feet. These constructed features would represent a further departure from the natural state of the river, and as such, would afford a negative visual impact. However, the area presently affords little visual access and the existing visual quality is not high.

At the outlet structure in Apponaug Cove, virtually everything is covered by water. The only exposed port[illegible] would be a horseshoe shaped wall partially enveloping the outlet works and extending to about 12 feet above mean sea level; the concrete piers and stoplog structure; and a maintenance and operation structure which would afford a negative visual impact.

Cultural and Historical Resources -- A preliminary analysis was conducted by the Rhode Island Historical Preservation Commission. The Commission indicated that potential archaeological damage resulting from construction of the diversion tunnel is difficult to assess at this time. Though no damage to known surface sites of national interest would result from the tunnel, there could be disruption on the floor of Apponaug Harbor. Due to the possibilities of the harbor having past archaeological significance, the potential impact is uncertain. An underwater survey of the area was conducted to evaluate its significance. The results of the study revealed nothing unique or of interest.

The tunnel will have no impact on the marsh areas near Gorton Pond as it will be constructed well below the surface in this area. The area of the intake structure of the diversion tunnel will also be surveyed before the final impacts are prepared in the Environmental Statement. The structure is not expected to have a visual or physical impact on either the locally significant Natick Mill Village District or the Westcott Mill Housing District located respectively, in and near, the vicinity of the diversion intake.

ECONOMIC EFFECTS

By implementation of the selected plan, numerous beneficial economic effects are expected to occur. A key short-run effect will be the availability of increased employment for many unskilled and semi-skilled laborers during the const[illegible]tion phase of the project. The actual number of jobs to be created at the current time is undetermined; however, jobs in this currently depressed industry (20% for construction trades) will be available for 3 to 4 years. In addition to the secondary impacts generated through the powerful economic multiplier, this project would provide an excellent stimulus to the State and study area economics.

The effect on long term variables with the project should be far greater. Capital, employment growth, industrial development, water-related industries and recreation, State taxes, land use and values will all be positively impacted. Recent changes in State tax policies are likely to have an impact on the intensity and diversity of industrial development as the area's attractiveness to industry changes with respect to other States of the nation. This has lead to a rapid industrial expansion in the past few years, and it is expected to occur in the future. Much of this development has occurred in the flood plain.

Conversely, by operation of the diversion, flood waters will enter Apponaug Cove and Greenwich Bay. As the shellfish industry has important socio-economic effects on the Narragansett Bay area an undetermined number of lost fishing days could be possible. This is determined by the duration of time that the coliform counts in Greenwich Bay exceed safe limits.

Negative impacts due to the construction of the diversion tunnel and its appurtenant structures are minimal. Some of the noises will be evident at the intake and outlet structures, but should be minor as the surrounding area is less habitated. At the intake structure, due to the construction site being located within sight of the existing Providence Street Bridge, traffic congestion may be a problem due to curiosity factors and increased activity.

As the construction of the tunnel and shafts will require blasting, the social impacts will be determined by the extent to which the inhabitants of the area react psychologically. During a past series of plan formulation meetings, several residents whose backyards would be directly over the tunnel, although separated by 200 feet of mainly rock cover, were afraid of the ground collapsing and caving in. Although this phenomenon could not happen due to the structural strength of the over-burden rock, the psychological fear would probably remain. This degree of unrealistic uncertainty has both a short run and a long term effect. Any activity which undermines public confidence in the security of the area will result in reactions that may range from organizing to prevent completion of the project to sale of property in the area.

Finally, construction of the outlet for the diversion involves impacts on recreation and businesses located in Apponaug Cove area. The impacts on recreation are of two types: direct interference with recreational activity caused by obstruction in Apponaug Cove itself and indirect interference of the use of surrounding land and/or water as a result of noise, dust and associated construction. Boating, shellfishing and use of beaches are all affected by these considerations. In addition, traffic congestion in the central area of Apponaug will be increased

during the construction phase. Since this is already an area of heavy traffic, increased congestion may interfere with access to businesses and with commuter patterns.

Long term impacts refer to the consequences of physical structures and to the developments in the area that are likely to be affected by the presence of the project. These developments are generally large scale changes that result from the interaction between the physical setting and the social and economic patterns of the communities. Although these changes cannot be specified as precisely as the consequences of physical structures, they are extremely important in gaging long-term impacts.

EFFECT ON REGIONAL DEVELOPMENT

All of the known and investigated effects under this account are beneficial. Most of these aspects have been mentioned earlier in terms of creating other adverse or beneficial impacts. The short range impacts will be limited to the phases of construction which will yield numerous jobs to the locally depressed construction trades. Through the multiplier effect more service type jobs will also be required. Long term effects will be attributed to the fact that as existing flood-prone lands are now substantially free, industry is likely to expand, again resulting in more permanent type job opportunities. As more jobs become available, more people are likely to move into the area to be near their place of employment. This will necessitate more construction of homes and also, through the multiplier, more service type jobs. As residential areas, previously flood-prone, are now dry, improvements can be made to an older home without fear of losing the initial investment. This will result in a more desirable type of community to live in and make the community cohesion even greater.

WARWICK AVENUE LOCAL PROTECTION PROJECT

Protection of this area would begin along a high ridge located on the southerly bank of the Pawtuxet River about .2 miles upstream from the Pawtuxet Dam. It would run approximately parallel to the present river channel and tie into an escarpment at river mile 1.5 or .4 miles west of Warwick Avenue. Approximately 900 feet of channel realignment would be required to eliminate a meandering oxbow. Approximately 6100 feet of walls & dikes, two vehicular gates and one stoplog structure would be required to protect this area.

Various heights of protection have been investigated throughout this study effort. The currently envisioned project would be built in conjunction with flood control storage at Big River Reservoir. If Big River Reservoir is not built, the protection project's design flood would have to be increased by an average of 2 feet. Appropriate plan, profiles and sectional views of the Warwick Avenue Local Protection Project are shown in the supplemental hydrology report on plates 6, 7, and 8. An artist rendition of this local protection is shown on the following page. Plate 4-4 illustrates the existing soil profile. Costs and benefits for this protection project are shown in Appendix 7.

This proposed project is designated to provide protection in accordance with the governing criteria establishing the Standard Project Flood level as an appropriate level for urban areas as long as excess benefits exist. Maximum velocities most likely to occur in the river channel along the protection project would range from 6 to 8 feet per second. For specific details on design, free board, velocities and interior drainage design, see pages 7 through 11 of the supplemental hydrology report included in this chapter.

Geological Features.

Reconnaissance of the site, together with pertinent soil information obtained from local construction projects, geologic maps and supplemented by 14 subsurface explorations provided the supporting data for this project.

Based on foundation conditions and the ready availability of large deposits of glacial till, sand and gravel, and suitable rock from commercial and undeveloped sources, an earth fill embankment with an inclined impervious seepage barrier has been selected for dike design. All dikes would have a top width of 12 feet with vertical on horizontal slopes of 1.0 on 2.5 for the riverside area, 1.0 on 2.0 for landside. the dike slopes would be protected against erosion with protection stone on the riverside slope and grass cover on the landside. Foundation seepage

would be controlled through a toe drain with a collector pipe at the landside toe of the drain. For the lower section, easterly of Warwick Avenue, berms, as shown on Plate 8 of the supplemental hydrology report would be provided along the embankment to counterbalance shearing action along a zone of peat and organic silt.

Unsuitable foundation materials within limits of the structures, including topsoil would be removed and where practical, would be utilized either as landfill for reshaping low-lying areas behind the protective works or disposed of appropriately.

The concrete floodwalls would generally consist of L and T walls, both having reinforcing steel and employed for excessive heights, with the former being utilized in conjunction with constrictive horizontal clearances. Deviation from this standard would involve a short section of all transition concrete walls which would be extensions of specified walls tying into the dikes or dikes wrapping around the walls to reduce emerging seepage. Typical sections and details of walls are shown on plates 7 and 8 of the supplemental hydrology report.

The concrete structures will bear on a thin layer of natural sandy soil overlying inorganic silt deposits or directly on the silt deposit. Settlement will be practically instantaneous and should be negligible. Foundation seepage will be controlled by a zone of sand fill on the landside of the structure.

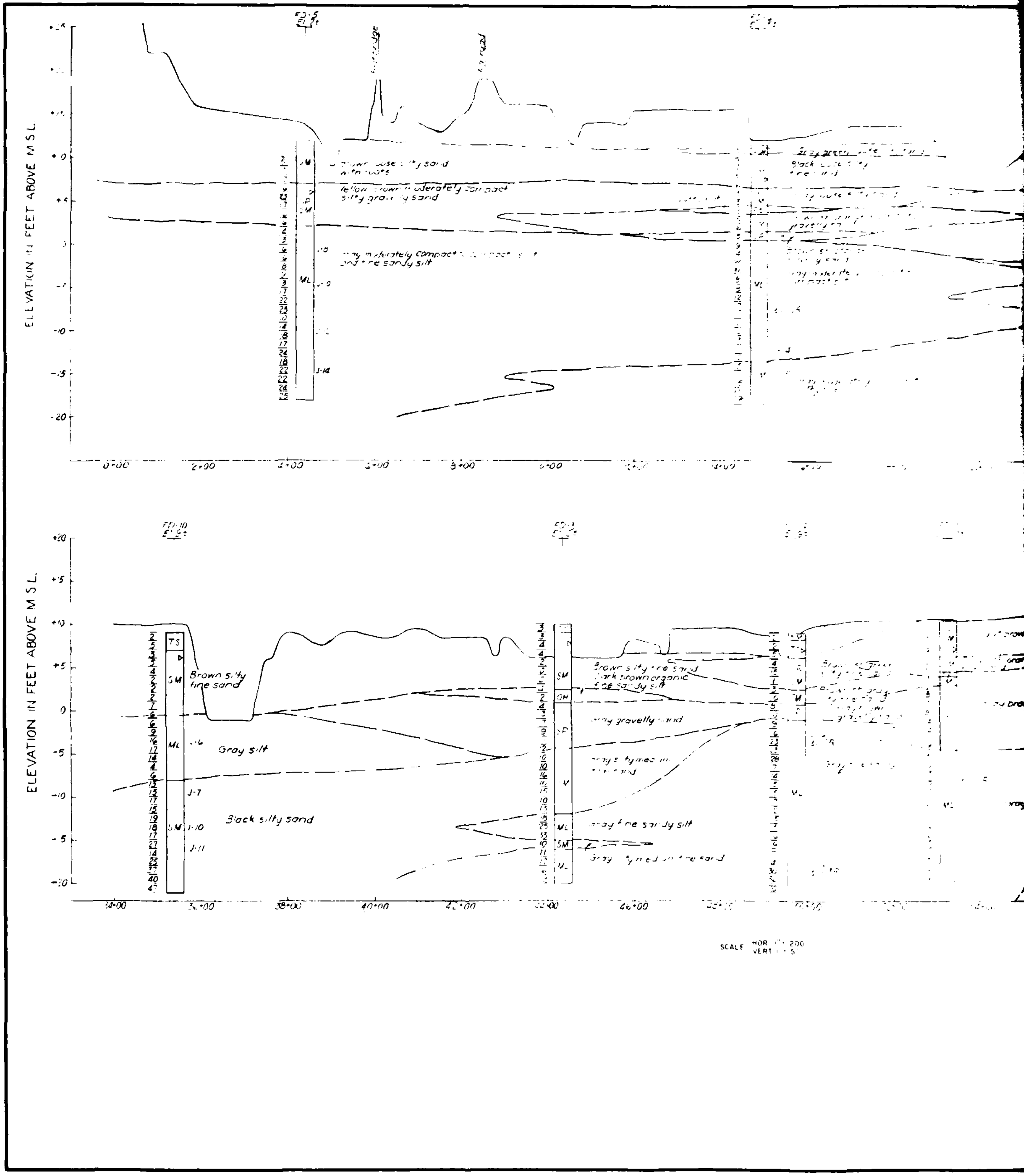
The earth dikes and concrete walls, measured along the centerline axis, would average about 12 to 16 feet in height for the Warwick Avenue section, as viewed from the river, the project would be about 19 feet above normal water surface, or 14 feet above original ground. Where feasible, there would be a minimum 20-foot buffer zone between the edge of the river and the toe of the protective works allowing present natural environment to remain.

Three movable closures would be required. Two would consist of steel vehicular hinged gages for the Ciba-Geigy pedestrian bridge and the combination railroad and highway bridge. A stoplog structure would be required at Warwick Avenue.

Excavations in the project area would be generally shallow consisting of the upper flood deposits of silty fine sand and stripping materials. The quantity of pervious material obtained from the required excavation would be small and mainly from the toe drain excavations or from the channel improvement.

<u>Construction Materials</u>

Potential sources of earth materials would be from off-site sources. Glacial till suitable for construction of impervious fills is currently


ELEVATION IN FEET ABOVE M.S.L.
ELEVATION IN FEET ABOVE M.S.L.
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+15
+10
+5
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-10
-15
-20
0+00
2+00
8+00
30+00
38+00
40+00
46+00
Brown silty fine sand
Gray silt
Black silty sand
gray gravelly sand
gray fine sandy silt
Brown silty fine sand
Dark brown organic fine sandy silt
Yellow brown moderately compact silty gravelly sand
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SM
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SP
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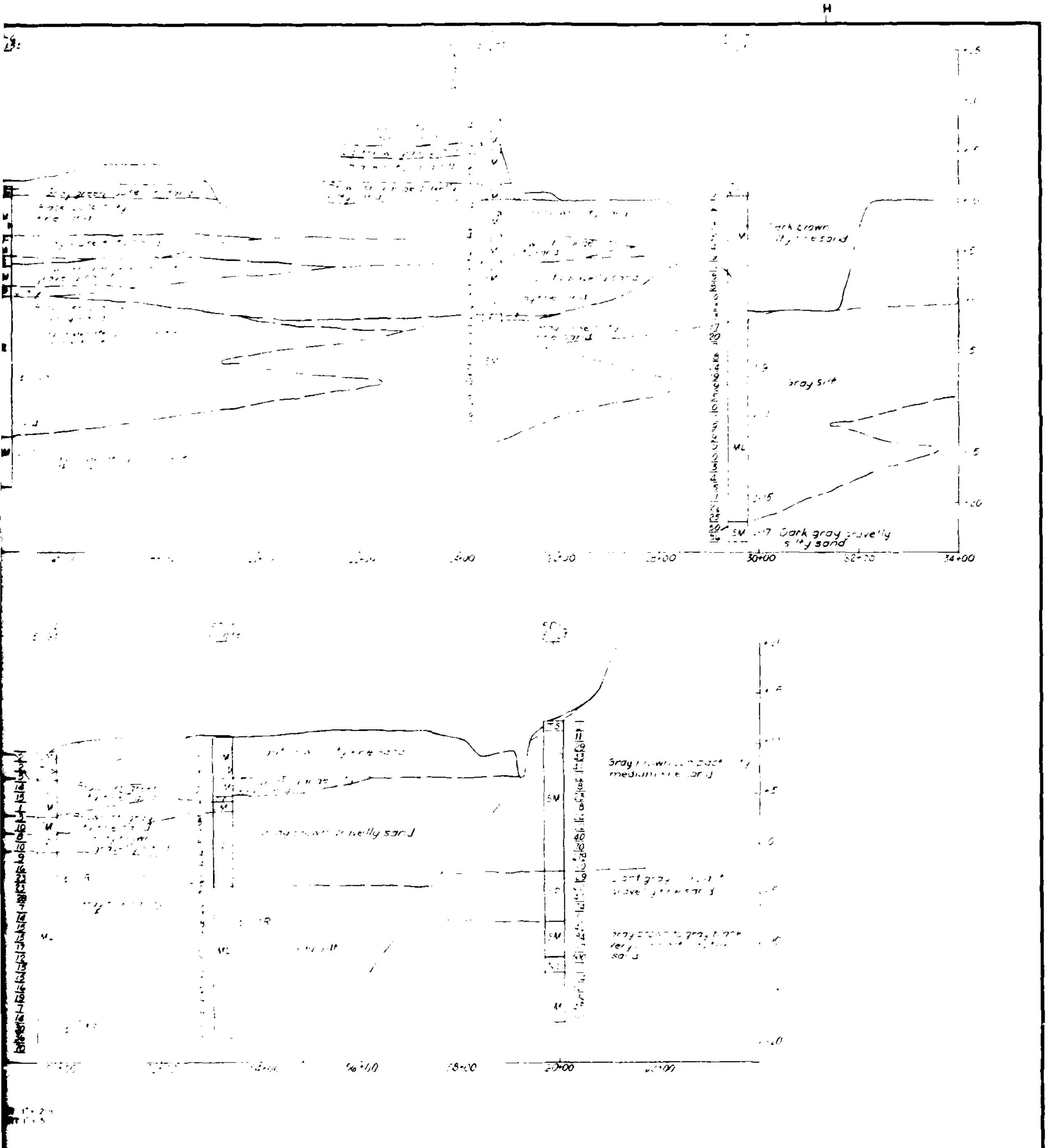
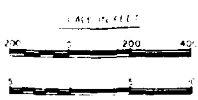
SCALE





WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN

RHODE ISLAND

WARWICK LOCAL PROTECTION

WARWICK AVENUE AREA

SOIL PROFILE

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION, CORPS OF ENGINEERS

WALTHAM, MASS

PLATE 4-4

available in sufficient quantity from undeveloped areas within a 15 to 20 mile radius. Bank-run sand and gravel for construction of pervious fills, gravel bedding, and drainage fills are available from commercial sources within 5 to 10 miles.

Quarried rock for protection stone may be produced by an operating quarry, located within 10 miles of the project area. Several commercial sources of crushed quarry stone, sand and gravel, and ready-mix concrete are located in the Providence area within a 15-20 mile radius of the project area. A producer of aggregate for concrete as well as ready-mix concrete is within only a few miles of the project location area.

Real Estate Acquisition

Cost estimates for real estate acquisition in conjunction with the project proposal were evaluated on comparable data of recent sales of residential, commercial and industrial properties within the entire project area. A thorough search of records in the communities to obtain names and addresses of affected owners, in addition to interviews with appraisers, real estate brokers, local officials, and knowledgeable people for obtaining and substantiating data and value estimates were conducted. The real estate estimates, as developed by the investigation, represents an unbiased judgment of the present fair market value of affected properties within the project area.

Total land acreage affected by local protective works would consist of 27.1 acres of land to be purchased in simple fee, in addition to about 10 acres of temporary easements for general work areas including space for minimal stock-filling of materials durng construction, the later all located in Warwick. The temporary easements would provide space for the storage of materials, equipment and contractor's work area during construction. Required acreage has been selected at ownerships that are unimproved lands but still contiguous to the proposed permanent easement areas. Cost of temporary easement are predicated upon a fair return of invested capital (fair market value) and a provision for estimated economic tax for the use of the land during the construction period. These easements have been estimated at $55,000.

Actual relocation of structures associated with project proposal would involve an industrially owned corrugated metal shed building having 3,000 square feet of floor space and located in the lower reaches of the Warwick Avenue area. The structure could be moved back on the same property away from the protective works.

The highest and best use of the required land for the local protective works is its present use. In the Warwick Avenue area current land use is mostly commercial and industrial. However, the portion which encompasses the protective works area is low and wet with sparsely tree-shaded areas along the riverbank. As the project area comprises mostly riverbank, it

is neither economically nor physically feasible for building purposes. Other deterrents are the State Coastal Resources Management Commission and the local zoning boards regulations governing the use of any land in close proximity to existing waterways.

As tabulated in the Table below, the land and water areas to be purchased in fee in Cranston (8.60 acres) would involve contiguous parcels associated with the 1,000 foot channel realignment located easterly of Warwick Avenue. The present centerline of the Pawtuxet River in this area in question is the city boundary between Cranston and Warwick. The present river channel is slated to be filled in with approximately 5.4 acres of land to be reclaimed. Of this useable land about 3.2 acres (excluding the area of dike embankment and 20 foot buffer zone behind the dike) would be in Cranston and the remaining 2.2 acres in Warwick. The estimated value of all the land is $120,000.

LAND AND DAMAGES
(Land in Fee/Permanent Easements)

By Category/ Community	Acres					
	Commercial	Industrial	Residential	Public	Water Area [1]	Total
WARWICK	3.5	10.7	0.8	--	3.50	18.50
CRANSTON	--	--	--	6.30	2.30	8.60
TOTAL	3.5	10.7	0.8	6.3	5.80	27.10

[1] Represents water area required either for project alignment or for operation and maintenance requirements.

As the project upon its completion would be turned over to non-Federal interests, disposal of reclaimed land would be an unimpaired local responsibility. In this instance, all three parties involved; namely, the State and the cities of Cranston and Warwick would have to mutually agree on its disposal. At this time, disposition of reclaimed land should be held in abeyance until the project becomes authorized by Congress with subsequent funding for the final design stage.

The local protective works would not interfere with the water requirements of any industrial facilities nor result in the loss of existing water rights.

Severance damages, an appraisal method reflecting actual value losses incurred with partial land acquisition would have an insignificant value for the Warwick Avenue area. For example, land to be acquired is low and primarily marshland, unsuitable for any type of improvement. It has little economic value and hardly any significant effect on the value of the remaining land. One accessory building is within the project area and will be removed. Hence, severance damages have not been included.

Acquisition costs which include mapping and surveys, legal description, title evidence, appraisal negotiations and closings, and administration costs for possible condemnation and relocation will affect 12 ownerships at a total estimated cost of $40,000. These 12 ownerships consist of all vacant tracts of land.

In accordance with Public Law 91-646, the Uniform Relocation Assistance Act of 1970 provides for uniform and equitable treatment of persons displaced from their homes, businesses or lands by a Federally-assisted program, to cover possible reimbursable expenses which may be incurred in the acquisition program involving the 12 unimproved ownerships. The cost for relocation assistance is $4,000.

To provide for possible appreciation of property values from the time of this acquisition date, for possible minor property line adjustments or for additional hidden ownerships which may be developed by refinement of taking lines, for adverse condemnation awards and to allow for practical and realistic negotiations, a contingency allowance of 20 percent has been considered to be reasonably adequate.

Total costs of lands and damages involving lands in fee and improvements, permanent and temporary construction easements, relocation assistance and acquisition costs including contingencies for possible appreciation of property value updated to present values, are estimated at $300,000. These costs are summarized in the following table, by category, and in a manner as to differentiate between Federal and non-Federal costs. As mandated by law, the costs of land and damages for the local protective works of the Warwick Avenue area, amounting to about $300,000 would be borne by local interests.

LANDS AND DAMAGES
TOTAL COSTS

	Warwick Avenue Local Protection Works
Lands and Improvements (Fee/Permanent Easement)	$120,000
Temporary Construction Easements	55,000
Acquisition Costs	40,000
Relocation Assistance Costs	4,000
Contingencies	44,000
TOTAL LANDS AND DAMAGES COSTS	263,000
updated to Dec 78	27,000
	$290,000

Rights-of-Way

The rights-of-way lands (included in lands and damages costs) can be defined as an area generally running parallel to project alignment with horizontal landward distance, measures from rear of walls or heel of dikes (landside toe) giving minimum widths varying from 15 feet (due to building constrictions) to 20 feet. The protective works would be offset a distance of 20 feet, wherever possible, from the river's edge for preserving the natural environment. The rights-of-way would also include lands within this buffer zone. These rights-of-way would also extend the entire length of the project including the peripheral land areas around the pumping station, land paralleling the pressure conduit and land area of the river oxbow. As this latter area would involve reclaimed land, final land disposition would be held in abeyance for final design stage, as would disposition of partial parcels of lands acquired as severance damage in order to comply with zoning regulations. Under no circumstances would the final rights-of-way in these areas be less than the prescribed 20 foot buffer zone strip.

Exclusive of the land adjoining Warwick Avenue, all rights-of-way lands, though industrially zoned, are not economically or physically feasible for building purposes, as they comprise mostly riverbank with zoning regulations discouraging or prohibiting its development. As the commercial land along Warwick Avenue is currently developed, the required rights-of-way land would also have insignificant effects on its present use. As access to the area for operation and maintenance function can be provided via public ways, additional rights-of-way lands are considered unessential at this time.

Relocation or Modification

The center of the Pawtuxet River is the city boundary between Cranston and Warwick project area. Relocation or modification of public utilities, such as power, telephone and gas lines would be minimal. Other modifications of public utilities would involve underground conduits in conjunction with the stoplog barrier and concrete floodwalls adjoining Warwick Avenue. This modification is considered minute as it can be simultaneously phased in with construction of the structural components at a negligible cost. Relocation or modification of private utilities would be associated with the Geigy industrial complex, involving a pedestrian bridge and a combination railroad and vehicular bridge and a sewer trestle crossing. Modification of utilities at these locations would also be considered negligible as they would be simultaneously modified in conjunction with the construction of the protective works.

Although the lands contiguous to the project area are serviced by public and private roads, relocation or modification of access roads would be minimal.

As mandated by law, cost contribution required of local interests in conjunction with reloction or modification features would be confined to that portion of the project involving local protective works for the Warwick Avenue area. These cost contributions are currently considered minor and adequately covered under the contingency items of land and damages. Further detailed evaluation would be made during final design stage.

Loss of Taxes

Discussions with local assessors and a review of the community records indicate the tax loss on fee simple taking, as a result of the project, would be negligible.

Construction Period

It is envisioned that the protective works could be satisfactorily accomplished within an intermediate frame of 3 years.

Operation and Maintenance

As the city of Warwick would be the single recipient of the benefits from the protective works, it would be responsible for its maintenance and operation. These functions would be limited to the normal upkeep of the dikes and walls including the remaining project areas, the pressure conduit and gravity gated outlets and operation of the pumping station, all in accordance with prescribed regulations established by the Secretary of the Army. These local costs have been estimated to be about $10,000 annually.

Major Replacements

This would include an allowance for project items deemed to have a usable life less than that of the project. Major items considered within this purview included gates of gravity outlets and pumps at pumping stations including electrical and mechanical features. From previous experience with similar projects, it is assumed that, on the average, major replacements would occur every 25 years and 90 percent of these replacement items would be required. These are estimated to be less than $5,000 for the local protective works.

Beautification and Recreation

The plan would insure that all project components be as visually acceptable as possible with inclusion of beautification and landscaping measures being an integral part of the selected plan. Special attention would be afforded for specific project components as follows:

It is proposed that all areas paralleling the dikes and walls on the landward side be landscaped, where practical, for harmonious blending with the area. The pumping stations and all retaining walls would be designed primarily according to the practical demands of the project with attention directed to aesthetic details to provide architectural compatibility with surrounding area particularly in light of the urban environment. In the immediate vicinity of the pumping stations planting of shrubs and trees would be considered for screening these facilities.

Consideration was also given to the possibility that certain areas along the project could be developed for limited public use activities. Such a suggestion was advanced by the Pawtuxet River Authority for the easterly side of the Warwick Avenue area. This would have included a pedestrian walk/bikeway beginning at Warwick Avenue, running along and/or parallel to the project and terminating at an arterial street on the east. Detailed items for enhancing the recreational uses of the neighborhood would have included benches, small fishing piers, picnic tables with trash barrels, to name a few. Another suggestion would include a river crossing from Warwick to land currently owned by the State in Cranston with subsequent recreational expansion of that existing State land. Such a suggestion does not appear possible.

The benefits and costs of the Warwick Local protection are discussed in Appendix 7.

EFFECTS OF THE WARWICK LOCAL PROTECTION ON FLOOD DAMAGES

The area protected by the Warwick local protective works would amount to about 190 acres. An artist's rendition of this local protective works with the new flood free area follows this page. This system of walls and dikes would cause some loss in natural valley storage with a subsequent slight increase in river stages on the opposite bank in Cranston, however, this increase would be more than compensated for by the reduction in flood stages produced by Big River Reservoir.

During a flood emergency all previously flood prone structures now protected by this project could continue performing their normal daily routine without any major change. The only exception would be on the occurrence of an extremely rare event where access to Ciba Geigy to and from the Cranston side would be prohibited due to the gate closures. However, in this type of occurrence, much of the firm's Cranston property would be inundated resulting in a probable plant shut-down. Warwick Avenue may also have to be closed off by the stoplog structures if the event was extremely rare. The distance traveled due to these temporary detours would probably not exceed 6 miles.

EFFECTS ON THE ENVIRONMENT

Freshwater Flora and Fauna - The most significant impact upon aquatic biology will be created by the elimination of a constrictive oxbow located in the lower reaches of the Warwick local protection project. Approximately 1,000 feet of new channel will be constructed with about 2,000 feet of old river channel eliminated. This channel realignment will result in the loss of about 6.3 acres of vegetated land, which probably supports small amounts of such mammals as moles, muskrats, racoons, cottontail rabbits, squirrels, woodchucks, mice and skunks.

The vegetational community for both areas consists of wooded swamp species such as red maple, red ash, aspen and swamp white oak, with high bush blueberry, sweet laurel, dogwood, alder and willow. Various grasses and sedges along with ferns and mosses form the ground cover. Groups of skunk cabbage and cowslips are also present. A total land requirement of about 27.1 acres will be necessary for the construction of the local protection project. Less than 50 percent of the land has limited if any, significant vegetational community. Where possible, the earth-rock fill dikes and concrete flood walls will be offset about 20 feet from the edge of the existing river bank. This will help re-establish any vegetational or animal life that is displaced during construction activities.

Water Pollution - With the construction of the Warwick local protection project, there will be no appreciable day to day improvements in the overall water quality of the lower Pawtuxet River.

Noise and Air Pollution - During the construction phase of the Warwick local protection project significant adverse impacts would likely occur. A prime source of noise will be the large ten wheel dump trucks hauling material to the project site or away to disposal areas. The key impacted areas will be along Warwick Avenue (RI 117) in Warwick.

This road is travelled regularly by heavy trucks and in far greater numbers. Additional noise will be evident where earth moving type equipment will be predominant. Numerous structures are located adjacent to the proposed walls and dikes. Although Federal noise standards for urban areas should help eliminate most of the harmful aspects of noise, there will still be a significant inconvenience created. The increased noise and possible traffic congestion at the construction site could result in a temporary loss of business for some of the merchants in the local area. Similarly, the residential homes will also feel the discomfort of the increased noise activities.

Throughout the duration of the construction activities, the air quality will be degraded. This will be attributable to the hauling of the spoil, and the disposal at either the local protection project site or other selected spoil areas. Other factors which would also degrade the air quality would be the deisel exhaust emissions from the earth moving equipment and hauling equipment, and the dust particles created by this equipment. All of these conditions will be temporary in nature due to the construction activities.

Land Use - As the selected plan will provide a high degree of flood protection for the areas within the Warwick local protection project all lands would now be flood free from events equalling a standard project flood level. Consequently, this will increase the value of the land and make it more highly desirable for development. The new growth anticipated as a result of the implementation of the selected plan should conform with the zoning regulations of the municipality, and as such, would probably not be considered adverse with respect to local plans.

The specific impacts of each segment of the selected plan with respect to land usage is discussed as follows:

Approximately 27.10 acres of land will be required for the Warwick local protection project. Most of the land required for the Warwick Avenue area is industrially and commercially zoned; but because most of it is low, frequently wet and located next to the riverbank, its acquisition should pose no constraints to development of other vacant land adjacent tot he project. Where there is limited clearance between the edge of the river and the protective works, concrete flood walls are used in lieu of the earth-rock filled dikes, resulting in significantly less land takings and reloctaion of structures.

A small portion of land acquisition at the constrictive oxbow, totalling about 8.60 acres and located entirely in Cranston, involves part of the Pawtuxet Reservation currently owned by the State of Rhode Island. As this segment of land has limited recreational use, consisting principally of several trails used mainly as passageways leading to a baseball field from Warwick Avenue, its severance should have a negligible impact on the remaining recreational land.

Aesthetic Impacts - The primary impact of the selected plan would be the appearance of the walls and dikes at the Warwick local protection project with the obstruction of views they would cause. As the area is characterized by moderate to heavy commercial and industrial usage, it is unlikely that the presence of a dike along this section of the river would be detrimental in terms of aesthetics or obstruction of views.

Cultural and Historical Resources - According to a preliminary analysis conducted by the Rhode Island Historical Preservation Commission, the Warwick local protection project would not have an impact on historically or archeologically significant properties.

Recreational Resources - The selected plan will have little or no overall impact on existing recreational resources within the study area. The plan, if implemented, would help prevent flooding for nearly all of the lands which currently offer recreational amenities. The plan would affect the amount of potential recreational lands in the project area.

As the Warwick Avenue portion of the local protection project would eliminate the oxbow in the existing river, a small amount of recreational land would be lost. In terms of total recreation resources in the area, however, this loss is of minor significance.

ECONOMIC EFFECTS

By implementation of the selected plan, numerous beneficial economic effects are expected to occur. A key short-run effect will be the availability of increased employment for many unskilled and semi-skilled laborers during the construction phase of the project. The actual number of jobs to be created at the current time is undetermined,however, jobs in this currently depressed industry (20% for construction trades) will be available for years. In addition to the secondary impacts generated through the powerful economic multiplier, this project would provide an excellent stimulus to the State and study area economics.

The effect on long term variables with the project should be far greater. Capital, employment growth, industrial development, water-related industries and recreation, State taxes, and land use and values will all be positively impacted. Recent changes in State tax policies are likely to have an impact on the intensity and diversity of industrial development as the area's attractiveness to industry changes with respect to other States of the nation. This has lead to a rapid industrial expansion in the past few years, and it is expected to occur in the future. Some of this development has occurred in the flood plain.

EFFECTS ON SOCIAL WELL-BEING

In the short run, traffic, noise and dust will all be significant effects. Each of the communities in the impact area may be affected by these in different ways. For the local protection project, the impact of construction on traffic is important as it borders a major highway. The construction of flood gates on Warwick Avenue may increase traffic disturbance for a short period of time. The impact of the total construction activities on business could be significant where increased construction activities could induce the public to shop elsewhere.

EFFECT ON REGIONAL DEVELOPMENT

All of the known and investigated effects under this account are beneficial. Most of these aspects have been mentioned earlier in terms of creating other adverse or beneficial impacts. The short range impacts will be limited to the phases of construction which will yield numerous jobs to the locally depressed construction trades. Through the multiplier effect more service-type jobs will also be required. Long term effects will be attributed to the fact that as some existing flood

prone lands will now be substantially flood-free, industry is likely to expand, again resulting in more permanent type job opportunities. As more jobs become available, more people are likely to move into the area to be near their place of employment. This will necessitate more construction of homes and also, through the multiplier, more service type jobs. As residential areas, previously flood prone, are now dry, improvements can be made to an older home without fear of losing the initial investment. This will result in a more desirable type of community to live in and make the community cohesion even greater.

ELMWOOD AVENUE LOCAL PROTECTION

This project would consist of a system of walls and dikes. It would start at river mile 1.9 on the right bank in Warwick and be approximately 600 feet inland due to lack of high ground. The dike would proceed in a northeasterly direction running parallel with the river around the Norwood-Belmont peninsula, the reverse direction to the west, cross Elmwood Avenue, and then tie into high ground behind the present site of the American Lumber Company. It would terminate about 1200 feet southwesterly of Elmwood Avenue. An artists rendition of this project follows. For plan, profile and typical sections of this area, see Plates 10 and 11 of the supplemental hydrology report.

As the project protects residential homes in a highly urban area, current guidelines call for the design of the structure to be based on the Standard Project Flood. Numerous cost estimates, all based upon different design levels and/or conditions, have been made throughout the conduct of this study. The most recent is based upon the Standard Project Flood as modified by Big River Reservoir. For particulars on the design discharge, profiles, velocities, height of protection and interior drainage, see the supplemental hydrology report, pages 11, 12 and 13.

Based on foundation conditions, and the ready availability of large deposits of glacial till, sand and gravel, and suitable rock from commercial and undeveloped sources, an earth fill embankment with an impervious seepage barrier has been selected for dike design. All dikes would have a top width of 12 feet with vertical on horizontal slopes of 1.0 on 2.5 for the riverside and 1.0 on 2.0 for the landside. The dike slopes would be protected against erosion with protection stone on the riverside slope and grass cover on the landside. Foundation seepage would be controlled through a toe drain with a collection pipe at the landside toe of the drain. As the foundation settlement of approximately 1.5 feet would be anticipated in the loose inorganic silt in the upper extremeties of the Elmwood Avenue Area, the embankment in this area may have to be overbuilt in height to compensate for the anticipated settlement. Unsuitable foundation materials within the limits of the structures, including topsoil could be removed and where practical, would either be utilized as land fill for reshaping low-lying areas behind the protective works or appropriately disposed of.

The concrete structures in the downstream portion of the Elmwood Avenue area will bear on a pervious zone of silty sand gravel or silty gravelly sand. As settlement would be practically instantaneous, no foundation problems are anticipated for the pumping station. In the upstream portion of this area structures will bear on loose inorganic silt. To negate this effect, steel sheet piling would be driven to a refusable depth of about -19 feet, N.G.V.D., with I walls atop the piles.

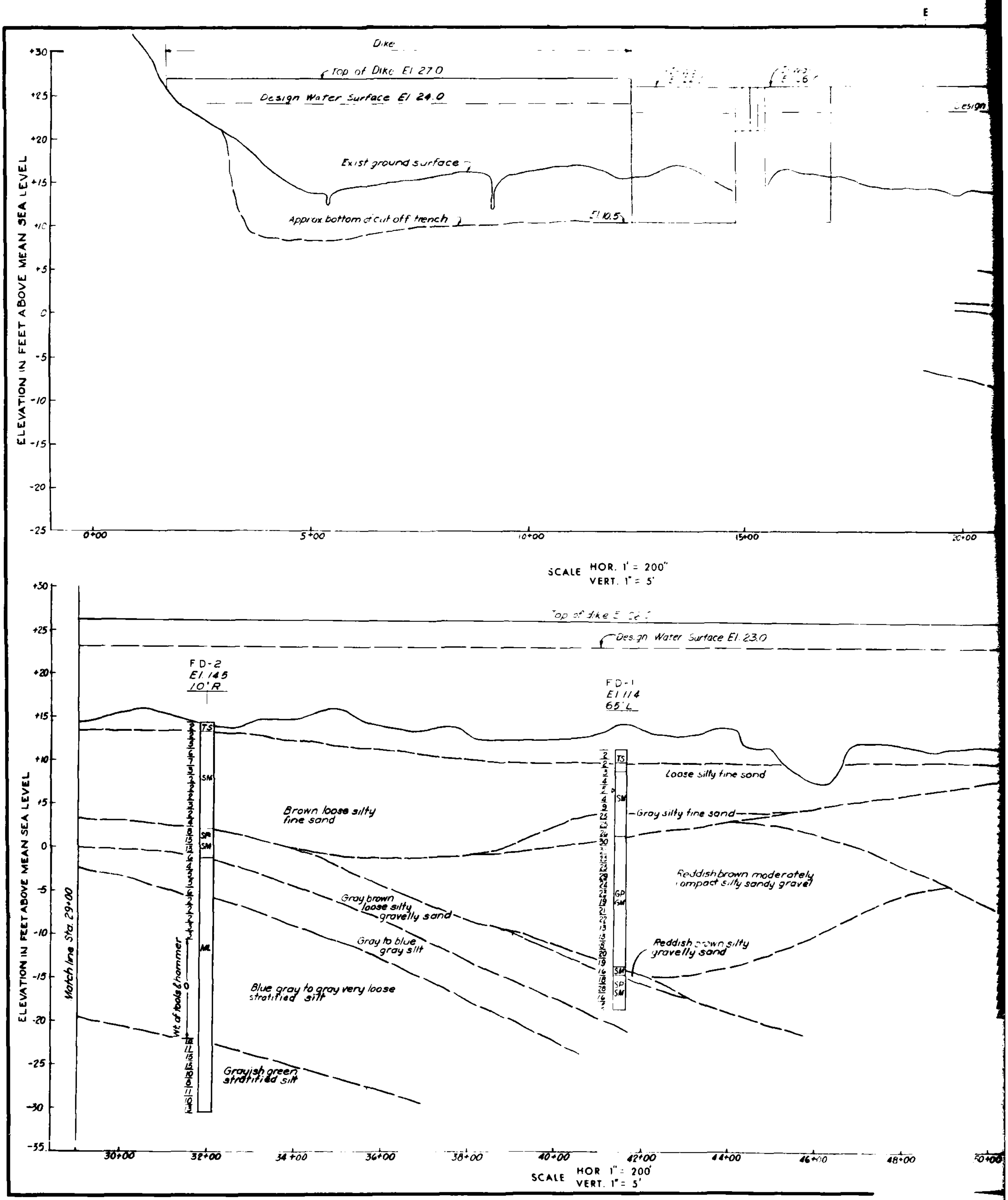
The earthfill dikes and concrete walls measured along the centerline axis would average about 16 to 18 feet. Wherever feasible, there would be a minimum 20 foot buffer zone between the edge of the river and the toe of the protective works allowing present natural environment to remain. If there is not ample room for this 20 foot buffer zone as different dike section must be used which has a 30 foot stabilization berm to counteract the various forces.

<u>Geotechnical Features</u>

In the Elmwood Avenue area, along the upstream half of the project, the foundation soil consists of about ten feet of flood plain deposits of loose silty fine sand overlying a loose pervious layer three to five feet thick of silty gravelly sand, and overlies a thick lake bed deposit of loose grey to dark grey and grayish green stratified silt. The density of the silt deposit varies with depth, from loose to very loose to moderately compact. In the remaining downstream half of the project, the foundation soil consists of two to eight feet of loose silty fine sand overlying very pervious loose to moderately compact silty sand gravel and silty gravelly sand. No evidence of bedrock was encountered in explorations of 45 foot depth. The soil profile of this area is shown on plate 4-5.

<u>Real Estate Acquisition</u> - Cost estimates for real acquisition in conjuntion with the project proposal were evaluated on comparable data of recent sale of residential, commercial and industrial properties within the entire project area. A thorough search of records in the communities to obtain names and addresses of affected owners, in addition to interviews with appraisers, real estate brokers, local officials, and knowledgeable people for obtaining and substantiating data and value estimates were conducted. The real estate estimates as developed by the investigation represent an unbaised judgement of the present fair market value of affected properties within the project area.

Total land acreage affected by the Elmwood Avenue local protective works, would consist of 16.16 acres of land to be purchased in simple fee, excluding temporary easements for general work areas including space for minimal stockfilling of materials during construction. This will amount to less than 5 acres. This is broken down into the following categories: commercial - 1.77 acres; industrial - 2.61 acres; residential - 4.91; public - 6.64; wetland/water - 0.23 acres.


E
Dike
Top of Dike El 27.0
Design Water Surface El 24.0
Exist ground surface
Approx bottom of cut off trench
El 10.5
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
0+00
5+00
10+00
15+00
20+00
SCALE HOR. 1" = 200' VERT. 1" = 5'
Top of dike
Design Water Surface El. 23.0
FD-2 El. 14.5 10' R
FD-1 El. 11.4 65' L
Watch line Sta. 29+00
Wt of tools & hammer
Loose silty fine sand
Gray silty fine sand
Brown loose silty fine sand
Reddish brown moderately compact silty sandy gravel
Gray brown loose silty gravelly sand
Gray to blue gray silt
Reddish brown silty gravelly sand
Blue gray to gray very loose stratified silt
Grayish green stratified silt
30+00
32+00
34+00
36+00
38+00
40+00
42+00
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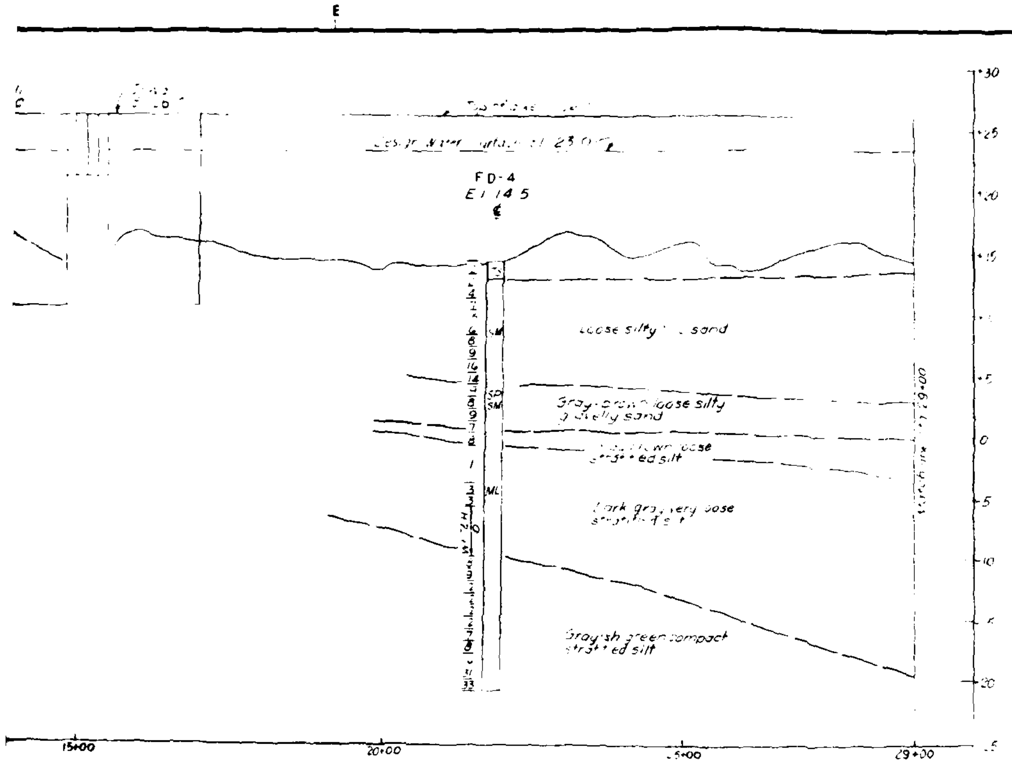
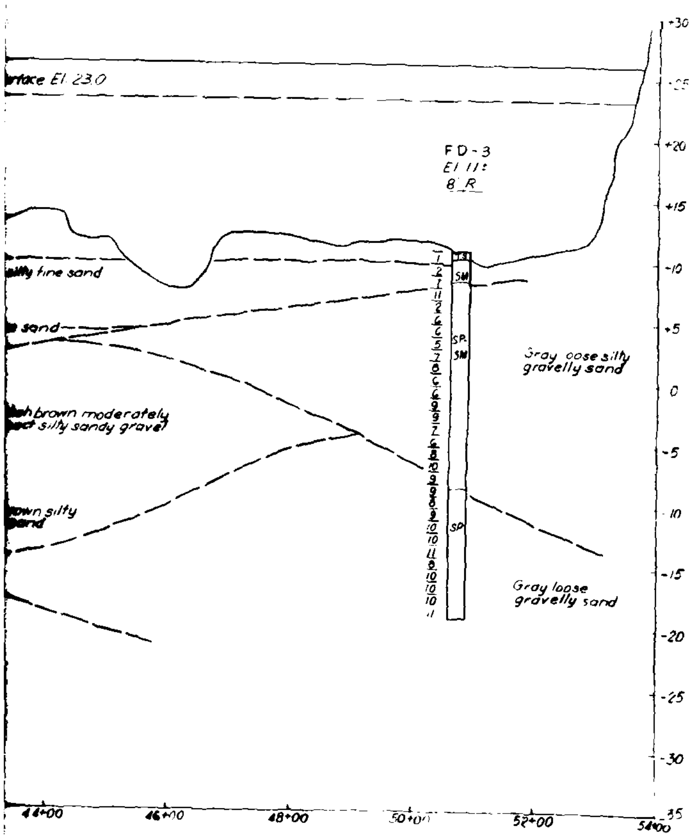
48+00
50+00
SCALE HOR 1" = 200' VERT. 1" = 5'





LEGEND

FD	FOUNDATION DRIVE SAMPLE BORING
EL 14.5	ELEVATION OF GROUND SURFACE AT TIME OF EXPLORATION
10'R	LOCATION BY STATION AND OFFSET FROM DIKE CENTERLINE
14	NUMBER TO LEFT OF BORING IS NUMBER OF BLOWS PER FOOT OF PENETRATION USING A 350 POUND HAMMER FALLING FREELY AN AVERAGE OF 18 INCHES ON A SAMPLE SPOON USUALLY EQUIPPED WITH A BEVELLED DRIVE SHOE.
ML	GROUP SYMBOL ACCORDING TO UNIFIED SOIL CLASSIFICATION SYSTEM.

SCALE IN FEET

100' 0 100' 200'

5' 0 5' 10'

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN

RHODE ISLAND

WARWICK LOCAL PROTECTION

ELMWOOD AVENUE AREA

SOIL PROFILE

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 4-5

Improvements or buildings to be purchased outright would involve 7 residences, on the easterly side of the protective works. Relocation of these residential dwellings could be accomplished at minimal costs with least social disruption by moving the homes within, but away from the protective works. As there is in most cases, insufficient available land on some property to conform to single residence zoning regulations, most of the involved homes could be relocated to city-owned land away from project alignment so as to satisfy local zoning ordinances. However, for purposes of this study, outright purchase of these seven dwellings is the considered action with relocation potentials to be considered in the advanced design stage.

Temporary easements, as a provision for providing space for the storage of materials, equipment and contractor's work area during construction, would also be required. Required acreage has been selected at ownerships that are unimproved lands but still contiguous to the proposed permanent easement areas. Cost of temporary easement are predicated upon a fair return of invested capital (fair market value) and a provision for estimated economic tax for the use of the land during the construction period. Temporary easement would involve about 4.0 acres in Warwick.

The highest and best use of the required land for the local protective works in the Elmwood Avenue area is its present use, primarily residential with a small portion classified as heavy commercial and light industrial. Many of the residential lots are varied in size, comprising low wetland and have no physical access to either public or private roads. In certain area, what appears to be access roads on the assessor's maps are only proposed streets. In the absence of flood plain zoning regulations and with adequate sewage facilities, this area would be potentially available for residential development.

The severance damages for the project proposal are estimated to be about $40,000. Acquistion costs which include mapping and surveys, legal description, title evidence, appraisals, negotiations and closing, and administration costs for possible condemnation and relocation will affect 22 ownerships at a total estimated cost of $66,000.

In accordance with Public Law 91-646, the Uniform Relocation Assistance Act of 1970 which provides for uniform and equitable treatment of persons displaced from their homes, businesses or lands by a Federally-assisted program, a total sum of $50,000 is estimated to cover possible reimbursable expenses which may be incurred in the acquisition program.

To provide for possible appreciation of property values from the time of this acquisition date, for possible minor property line adjustments or for additional hidden ownerships which may be developed by refinement of taking lines, for adverse condemnation awards and to allow for practical and realistic negotiations, a contingency allowance of 20 percent has been considered to be reasonably adequate.

Total costs of lands and damages involving lands in fee and improvements, permanent and temporary construction easements, severance damages, relocation assistance and acquisition costs including contingencies for possible appreciation of property value are estimated at $650,000. These costs are shown below by category.

Lands and Improvements (Fee/Permanent Easement)	$350,000
Temporary Construction Easements	30,000
Severance Damages	40,000
Acquisition Costs	80,000
Relocation Assistance Costs	60,000
Contingencies	$112,000
	672,000
updated Dec 78	48,000
	$720,000

<u>Rights-of-Way</u> - The rights-of-way lands pertaining to the Elmwood Avenue local protective works can be defined as an area generally running parallel to project alignment with horizontal landward distance, measures from rear of walls or heel of dikes (landside toe) giving minimum widths varying from 15 feet (due to building constrictions) to 20 feet. The protective works would be offset a distance of 20 feet, wherever possible, from the river's edge for preserving the natural environment. The right-of-way would also include lands within this buffer zone. They would extend the entire length of the project including the peripheral land areas around the pumping station and land paralleling the pressure conduit. Final land disposition of partial parcels of lands acquired as severance damage in order to comply with zoning regulations would be held in abeyance for final design stage. Under no circumstances would the final rights-of-way in these areas be less than the prescribed 20 foot buffer zone strip.

Relocation or modification of public utilities, such as power, telephone and gas lines would be minimal.

<u>Loss of Taxes</u> - Discussions with local assessors and a review of the community records indicate the tax loss on fee simple taking, as a result of the project, would be about $3500 per annum.

<u>Construction Period</u> - This phase will run for two consecutive years.

As the city of Warwick would be the major, single recipient of the benefits from the Elmwood Avenue protective works, it would be responsible for its maintenance and operation. These functions would be limited to the normal upkeep of the dikes and walls including the remaining project areas, the pressure conduit and gravity gated outlets and operation of the pumping station, all in accordance with prescribed regulations established by the Secretary of the Army. These local costs have been estimated to be about $6,000 annually.

<u>Major Replacements</u> - This would include an allowance for project items deemed to have a usable life less than that of the project. Major items considered within this purview included sluice gates at the diversion intake, gates of gravity outlets, and pumps at pumping stations including electrical and mechanical features. From previous experience with similar projects, it is assumed that, on the average, major replacements would occur every 25 years and 90 percent of these replacement items would be required. These are estimated to be $2000 for the local protective works.

The cost estimate for the Elmwood Local Protective works is shown on Table 4-13, along with the cost of the lands and damages. Asuming a construction period of two years, the annual charges at 6-5/8% are as follows:

Total Project First Cost	$7,500,000
Interest during construction	476,900
	7,996,900
Interest plus amortization	530,700
Operation and maintenance	6,000
Interim replacements	2,000
Loss of Taken Land	3,500
	$ 542,200

The total annual benefits using methodology described in appendix 7 and utilizing ER 1105-2-351 are tabulated as follows;

Basic hydrologic benefits	$344,400*
Location benefit	0
Economic growth 1972-1985	0
Economic growth 1985-2035	50,000
*using damage survey of March-April 1979	$394,400

Thus, the benefit to cost ratio is 0.73 for this single purpose measure.

TABLE 4-13
COST ESTIMATE
Elmwood Avenue Local Protection

	Elmwood Avenue	Unit Cost	Total
Preparation of Site	1	LS	$ 40,000
Control & Diversion of Water	1	LS	5,000
Common Excavation	42,000	$ 4.70	197,400
Protection Stone	24,000	35.00	840,000
Crushed Stone	10,000	9.00	90,000
12" Gravel Bedding	17,000	9.00	153,000
Compacted Gravel Fill	9,000	8.00	72,000
Compacted Impervious Fill	41,000	6.00	246,000
Compacted Sand Fill	3,000	6.00	18,000
Compacted Pervious Fill	75,000	6.00	450,000
Topsoil	2,000	8.00	16,000
Seeding	11,000	0.60	6,600
Concrete T walls	3,300	140.00	462,000
Concrete I Walls	200	140.00	28,000
Concrete Gate Structures	600	140.00	84,000
Cement	27,000	3.00	81,000
Reinforcing Steel	602,000	.50	301,000
Steel Sheet Piling	8,000	9.50	76,000
8" BCCMP	5,000	6.00	30,000
Street Gate	1	LS	75,000
Interior Drainage	1	LS	129,000
Pumping Station	1	LS	580,000
Pressure Conduit	1	LS	115,000
			$4,095,000
	20% Contingencies		819,000
			$4,914,000
	E & D - 15.0%		737,000
	S & A - 9.3%		457,000
			6,108,000
Updated to September 1978 Price Level			6,800,000
Lands and damages			720,000
			$7,520,000

PAWTUXET RIVER FLOOD CONTROL

HYDROLOGIC ANALYSIS

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PAWTUXET RIVER FLOOD CONTROL

HYDROLOGIC ANALYSIS

1. PURPOSE

The purpose of this report is to present the hydrologic data and analysis for flood control on the Pawtuxet River. Included are sections on basin description, climatology, analysis of floods and hydrologic engineering related to the plans of improvement for flood control.

2. BASIN DESCRIPTION

a. General. The Pawtuxet River basin shown on plate 1 lies entirely within the State of Rhode Island and covers a total area of 230 square miles. The basin is triangular in shape with a north-south base of 23 miles and an east-west length of about 18 miles. Drainage in the basin is generally west to east and the watershed has a variable hydrologic character. The westerly headwater region is quite hilly with little urban development, whereas the lower easterly portion is very flat and quite highly urbanized. The water resources of the westerly headwater region have been extensively developed for domestic and industrial water supply. Scituate Reservoir with a surface area of 3,400 acres at spillway crest and a drainage area of 93 square miles, is the dominating water supply system in the region. There is little water resource development in

the lower basin. Elevations in the basin vary from a high of about 800 feet msl at the westerly divide to a low of 10 feet msl near the mouth of the river.

b. Main River. The main stem Pawtuxet River originates at the confluence of the North and South Branches at River Point in West Warwick, Rhode Island. It then flows northeasterly between low banks for 10.9 miles to its mouth in Pawtuxet Cove. The river averages about 100 feet in width and about 4 feet in depth throughout its length and has an average slope, excluding drops at three existing run of river dams, of approximately 2.6 feet per mile. From its origin to the mouth the river has a total fall of about 50 feet. Originally. approximately 3 miles of the lower reach of the river was a tidal estuary until the construction of the Pawtuxet dam near the mouth of the river in 1870 to prevent salt water intrusion. In the lower reach the main river is joined by two other tributaries from the north, Meshanticut Brook and Pacasset River, at river miles 9.0 and 3.8, respectively. The river profile is shown on plate 2.

c. Tributaries.

(1) North Branch. The North Branch of the Pawtuxet River has a drainage area of 106 square miles and originates at Scituate Reservoir. Kent Dam, which forms the Scituate Reservoir, has a drainage area of 92.8 square miles. From the tailwater of the dam the river flows for 6.8 miles in a general southeasterly direction and falls

145 feet. In this reach, it flows through a succession of seven small run of river dams and pools to its junction with the South Branch at River Point. The river profile is shown on plate 3.

(2) South Branch. The South Branch of the Pawtuxet River, with a drainage area of 73.0 square miles, originates at Flat River Reservoir dam which has a drainage area of 56.7 square miles. From tailwater the river flows in a general northeasterly direction for 9 miles and falls 185 feet to its junction with the North Branch at River Point. Within this reach, the river meanders through marshes and a series of small storage ponds created by 11 mill dams. The river profile is shown on plate 3.

(3) Meshanticut Brook. Meshanticut Brook, with a drainage area of 15.0 square miles originates and flows generally southerly through the city of Cranston, Rhode Island to its confluence with the Pawtuxet at river mile 9.0. The river has a total length of about 6.5 miles and falls about 220 feet in the upper 2.9 mile reach and only 48 feet in its lower 3.6 mile reach. Development in the watershed varies from sparse in the upper basin to moderate in the lower basin.

(4) Pocasset River. The Pocasset River, with a drainage area of 20.8 square miles, originates in the town of Johnston and flows in a southeasterly direction through the city of Cranston, Rhode Island. In its 11.6 miles distance, it falls 275 feet to its junction

with the Pawtuxet River at river mile 3.8. In its course, the river falls 200 feet in its first 5-mile reach and 75 feet in its remaining length. The Pocasset River watershed is in the more highly developed areas of the Pawtuxet River basin. Pertinent data on the Pawtuxet River and its tributaries are given in table 1.

TABLE 1

PAWTUXET RIVER PERTINENT DATA

Name of Stream	Distance Above Pawtuxet Dam (river miles)	Total Drainage Area (sq. mi.)	Length (miles)
Pawtuxet River	0.0	230.4	10.9
Pocasset River	3.8	20.8	11.6
USGS Gage	4.5	200	-
Meshanticut Brook	9.0	15.0	6.5
North and South Branch Confluence	10.9	179.0	-
North Branch	10.9	106.0	6.8
Kent Dam (Scituate Reservoir)	17.7	92.8	
South Branch	10.9	73.0	9.0
Flat River Reservoir	19.9	56.7	

3. CLIMATOLOGY

a. General. The Pawtuxet River basin has a variable climate but,

due to its proximity to Narragansett Bay, escapes the severity of cold and depth of snowfall experienced in the higher elevations of the interior areas of New England. It frequently experiences periods of heavy precipitation produced by local thunderstorms and by intense "lows" of tropical and extra-tropical origin that move northeasterly up the coast. The basin also lies in the path of the prevailing "westerlies" which generally travel across the country in an easterly or northeasterly direction producing frequent weather changes.

b. Temperature. The average annual temperature of the Pawtuxet River basin is about 50° Fahrenheit. Extremes in temperature range from occasional highs of 100°F. to lows of -15° Fahrenheit. Freezing temperatures may be expected from the latter part of October until the middle of April. The mean, maximum and minimum monthly and annual temperatures for the period of record at Providence are shown in table 2.

c. Precipitation. The mean annual precipitation over the Pawtuxet River basin varies from about 40 inches in the lower coastal areas to about 48 inches in the uplands. The distribution of the precipitation is quite uniform throughout the year. However, extremes in monthly values range from a high of more than 12 inches to less than 0.20 inch on several occasions. The monthly and annual precipitation at Providence, representative of the lower coastal area, are shown in table 2.

TABLE 2

MONTHLY TEMPERATURE-PRECIPITATION

AT PROVIDENCE, RHODE ISLAND

Month	Temperature 40 Years of Record			Precipitation 40 Years of Record		
	Mean	Maximum*	Minimum*	Mean	Maximum	Minimum
January	29.3	65	-9	3.59	7.12	0.50
February	29.3	65	-15	3.23	5.63	1.31
March	37.5	86	1	3.67	8.31	1.49
April	47.5	87	14	3.55	7.32	0.72
May	57.8	94	29	3.10	9.25	0.57
June	66.9	97	39	2.91	7.21	0.04
July	72.6	99	46	3.05	6.92	0.24
August	70.8	100	40	3.58	12.24	0.82
September	63.8	99	32	3.25	9.74	0.77
October	54.0	88	21	3.00	11.89	0.16
November	43.4	81	12	3.65	8.50	0.67
December	32.4	69	-11	3.74	10.75	0.58
ANNUAL	50.4	100	-15	40.32	58.57	25.44

*Based on 31 Years of Record 1940-1970

d. Snowfall. The average annual snowfall over the Pawtuxet River basin, shown in table 3, is about 40 inches. Water content of the snow cover usually reaches a maximum about the first of March but rarely exceeds 2 to 3 inches due to the moderating effect of Narragansett Bay.

TABLE 3

MEAN MONTHLY SNOWFALL

AT PROVIDENCE, RHODE ISLAND

Elevation 51 Feet MSL
40 Years of Record
(Depth in Inches)

Month	Snowfall
January	10.2
February	10.5
March	7.8
April	0.5
May	0
June	0
July	0
August	0
September	0
October	T
November	1.3
December	7.8

Annual Average 37.50 Inches

4. STREAMFLOW

The U.S. Geological Survey maintains six stream gaging stations within the Pawtuxet River watershed. Pertinent data for the six stations is summarized in table 4 and the locations of the stations are shown on plate 1. One of the stations is located on the main stem of the Pawtuxet at Cranston and a second, on the South Branch downstream of Flat River reservoir at Washington, Rhode Island. These two main river gages have both been in operation since about 1940. The remaining four gages are located on headwater tributaries.

Average annual runoff from the Pawtuxet watershed is about 27 inches or approximately 60 percent of average annual precipitation. Monthly runoff at the two main river gages is shown in table 5.

5. TIDES

a. General. Two high and two low tides occur each lunar day in the Narragansett Bay area with a mean high water of 2.47 feet msl and mean low water of -2.13 feet msl at Providence. Predicted tidal data are given for 16 locations in the Narragansett Bay area in the annual Tide Table Publication of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, entitled "Tide Tables, East Coast of North and South America".

b. Storm tides. The Pawtuxet dam, constructed at the mouth of the river in 1870 with a crest elevation of 5.3 feet msl, prevents

TABLE 4

GAGING STATION RECORDS
PAWTUXET RIVER WATERSHED

Gaging Station	Drainage Area (sq. mi.)	Period of Record	Discharge (cfs) Mean	Maximum*	Minimum
Misquitahawk Brook nr. No. Scituate, R.I.	3.06	1965-present	-	630	-
Nooseneck River at Nooseneck, R.I.	8.23	1963-present	14.9	318	0.81
Carr River at Nooseneck, R.I.	6.73	1963-present	9.1	221	0.30**
So. Br. Pawtuxet R. at Washington, R.I.	63.8	1940-present	126	1,860	2.8
Furnace Hill Brook at Cranston, R.I.	4.19	1965-present	-	586	0
Pawtuxet River at Cranston, R.I.	200	1939-present	393	3,110	22**

*Maximum recorded flow occurred 18 March 1968
**Minimum daily flow

TABLE 5

MONTHLY RUNOFF
(In Inches)

Month	Pawtuxet River at Cranston Rhode Island (D.A. = 200 square mile)			South Branch Pawtuxet River at Washington, Rhode Island (D.A. = 63.8 square mile)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	2.98	6.56	0.78	2.83	5.84	0.69
February	3.15	7.38	1.34	3.02	4.54	1.33
March	4.57	7.47	2.56	4.25	6.64	2.66
April	3.86	7.01	1.24	3.83	6.49	1.22
May	2.65	5.38	1.34	2.81	5.61	1.24
June	1.40	3.96	0.24	1.61	4.37	0.49
July	0.77	2.52	0.002	0.94	2.29	0.28
August	0.78	3.43	0.06	0.88	2.81	0.29
September	0.86	4.96	0.11	0.91	4.16	0.28
October	1.09	6.48	0.20	1.21	5.81	0.45
November	2.01	5.74	0.43	1.97	5.85	0.50
December	2.81	5.99	0.67	2.77	5.63	0.66
ANNUAL	26.82	39.21	12.75	25.94	40.63	12.64

normal tides from affecting the lower Pawtuxet River; however, the dam is overtopped by abnormal storm tides. The lower Pawtuxet River is therefore subject to flooding from either fresh water flow or storm tides, or a combination of the two. The two greatest tides of record in recent years occurred as a result of hurricanes in September 1938 and August 1954. The maximum tidal level at Providence during these two events was 15.7 and 14.7 feet above msl, respectively.

c. Frequency of abnormal tides. The frequencies of abnormal tides in Narragansett Bay, in the vicinity of the mouth of the Pawtuxet River, were developed by the Corps of Engineers in 1960 in connection with the design of the Fox Point hurricane barrier at Providence. Tide frequencies were based on 26 years of continuous records plus historical accounts of earlier storm tides going back to the year 1635. The resulting tide frequency curve is shown on plate 4. Abnormal tide levels upstream of the Pawtuxet dam are generally about 2 feet lower then in the bay due to the hydraulic restriction posed by the dam. The project design hurricane tide for the Fox Point hurricane barrier, located just north of the mouth of the Pawtuxet River, was 20.5 feet above msl. It was concluded that a comparable storm tide upstream of Pawtuxet dam would be about 18.5 feet msl.

6. ANALYSIS OF FLOODS

a. General. The flood history of the Pawtuxet River demonstrates

that major floods can occur any season of the year as a result of intense rainfall alone or in combination with snowmelt. Flat River and Scituate reservoirs exert control over 66 percent of the Pawtuxet watershed and Scituate in particular has a significant modifying effect on flood development in the Pawtuxet basin. Pertinent data on Scituate and Flat River reservoirs is listed in table 6. The magnitude of fresh water floods on the main stem Pawtuxet are a function of: (1) storm rainfall and resulting runoff from the 80.9 square miles of watershed downstream of the reservoirs and (2) the initial storage capacity in the reservoirs and the resulting magnitude and timing of discharges from the reservoirs. Floods are also produced on the lower Pawtuxet by abnormal tides in Narragansett Bay. Following are discussions of some of the more notable floods that have occurred in the 19th and 20th centuries.

b. Historic floods.

(1) 22-23 September 1815. An abnormally high tide of 14.2 feet above msl in the Providence area resulted in extensive coastal flooding. It is reported that vessels were driven from their moorings and many wharves, stores, houses and barns were destroyed. There was apparently a relatively insignificant amount of coincident rainfall-runoff associated with this storm. Though flooding was undoubtedly extensive in the lower Pawtuxet River, destruction was minimized by the lack of development in the flood plain at this date.

TABLE 6

SCITUATE AND FLAT RIVER RESERVOIRS
PERTINENT DATA

	Scituate	Flat River
Drainage Area (sq. mi.)	92.8	56.7
Spillway Length (feet)	412	169
Spillway Elevation (ft msl)	284	248
Top of Flashboards (ft msl)	285.5	N.A.*
Storage Capacity		
Spillway Crest (acre-feet)	113,600	5,150
Spillway Crest (inches)	23	1.7
Top of Flashboards (acre-feet)	118,500	N.A.*
Top of Flashboards (inches)	24	-
Surface Area at Spillway Crest (acres)	3,400	850
Top of Dam Elevation (ft msl)	298	256

*Not applicable

(2) 11-14 February 1886. This flood was the greatest ever known on the main stem Pawtuxet River, resulting from 7 to 8 inches of rainfall over the basin augmented by snowmelt with an estimated water equivalent of 2 inches. Experienced flood levels were 6 to 7 feet higher then any other known flood before or since this event. There were no record of flows on the main stem but previous studies by the Corps estimated the discharge of the river was about 14,000 cfs in the vicinity of the present USGS gage site in Cranston.

Scituate Reservoir was not in existence at the time of this flood. If it had been built and initially filled, it is estimated the resulting flood at Cranston would have been modified to about 11,000 cfs. A recurrence of such a flood today, with present levels of development in the lower basin would result in a catastrophic type disaster.

(3) 2-4 November 1927. The heaviest rainfall associated with this major storm system occurred outside the Pawtuxet basin. Rainfall amounts varying from 2 to 7 inches were reported within the watershed. Scituate Reservoir stored 100 percent of the runoff from its watershed and only a minor flood freshet developed in the lower basin.

(4) 9-21 March 1936. The New England floods resulting from this storm were caused by a combination of heavy rainfall, deep snow cover, and unusually high temperature for the season. Rainfall in

the Pawtuxet basin was about 3.4 inches for the period 9-12 March and 3.1 inches for the period 18-22 March. Water equivalent of the snow cover, which was depleted during the period, was estimated at about 1 inch.

The flood was significantly modified by storage capacity initially available in the upstream reservoirs and the resulting peak flow of the Pawtuxet River in the vicinity of the present USGS gage in Cranston was estimated at about 5,300 cfs.

(5) 18-24 July 1938. This flood was the greatest experienced on the main stem Pawtuxet since the construction of Scituate Reservoir in 1926. It was the result of a coastal storm producing an average of 7 inches of rainfall over the Pawtuxet basin. This event occurred at a time when both Flat River and Scituate reservoirs were initially almost full; therefore, the only modifying effect was that due to surcharge storage. The resulting peak discharge at Cranston has been estimated at about 6,300 cfs. The flow components making up the July 1938 flood hydrograph at Cranston are graphically presented on plate 6.

(6) 17-22 September 1938. The hurricane of September 1938 produced an abnormal tide level in Narragansett Bay of 15.7 feet above msl in the vicinity of the mouth of the Pawtuxet River. This tide was 10.2 feet above the crest of the Pawtuxet dam and resulted in extensive tidal flooding in the lower reaches of the Pawtuxet River. The

rainfall of the preceding four days averaged 5 inches over the Pawtuxet watershed, but upstream reservoir levels were low and Pawtuxet River flows were not considered a major contributor to experienced floods.

(7) 31 August 1954. Hurricane "Carol" passed over the western portion of the basin creating abnormally high tides to elevation 14.7 feet above msl in Narragansett Bay near the mouth of the Pawtuxet River. The overtopping of Pawtuxet dam resulted in flood stages to approximately 12.5 feet msl upstream of the dam. Wind gusts over 100 mph were recorded at Providence during this hurricane. Precipitation associated with this storm was only about 3 inches over the basin and fresh water flooding was not a major factor.

(8) 17-18 March 1968. The 1968 event was produced by 4 to 7 inches of rainfall occurring in a 48-hour period. A preceding storm on the 12th and 13th of the month plus some snowmelt provided high antecedent runoff conditions. The resulting peak discharge at the USGS gage in Cranston was 3,110 cfs which was the greatest flow recorded since establishment of the gage in 1939. Though flood damages were not major, the event occurred following a period of very intensive development in the lower basin, and brought attention to the great flood damage potential to which most of this development was exposed. The 1968 flood discharge on the main stem Pawtuxet River was significantly modified by storage capacity initially available at Scituate Reservoir.

Had this reservoir been initially filled it is estimated the peak flow at Cranston would have been about 6,500 cfs or comparable to the experienced July 1938 flood when reservoirs were initially full.

Detailed analysis of the development of the March 1968 flood is graphically presented on plate 5. Pertinent data on the effects of Scituate and Flat River Reservoirs on historic floods is summarized in tables 7 and 8.

7. FLOOD FREQUENCIES

a. General. Flood frequencies for the Pawtuxet River were derived through analysis of historical flood discharge data within the basin, both recorded and computed, as well as by comparison with long term discharge records of streams outside the basin but in the general region. Peak discharge frequency curves were developed for (1) the Pawtuxet River at Cranston, (2) the South Branch at Washington (3) the uncontrolled 50.5 square mile local area downstream of the Flat River and Scituate Reservoirs to the Cranston gage and (4) the 30.4 local from the gage to the mouth of the river.

b. Pawtuxet River. Because of the complexity of the effect of upstream reservoirs on floodflows on the main stem Pawtuxet, conventional statistical flood frequency analysis of the data was not considered applicable. Instead, recorded annual peak flows and historical flood peaks were plotted using "Beard's" plotting positions and a

TABLE 7

FLOOD STORAGE BY UPSTREAM RESERVOIRS

	Scituate Reservoir (D.A. = 92.8 sq. mi.)				Flat River Reservoir (D.A. = 56.7 sq. mi.)			
	Initial Storage Capacity		Surcharge Storage		Initial Storage Capacity		Surcharge Storage	
	Inches	%Runoff	Inches	%Runoff	Inches	%Runoff	Inches	%Runoff
February 1886	Before Construction				0.48	10	1.51	30
November 1927	3.72	100	0	0	1.06	30	0.27	[illegible]
March 1936	3.21	60	1.47	28	0	0	0.76	14
July 1938	0	0	1.30	37	0.11	5	0.43	19
March 1968	2.24	100	*negligible*	*negligible*	0	0	.81	38

TABLE 8

ESTIMATED EFFECT OF UPSTREAM RESERVOIRS ON PEAK FLOWS AT CRANSTON, RHODE ISLAND

Flood	Flat River & Scituate Initially Filled To Spillway Crest (cfs)	With Complete Storage In Flat River And Scituate (cfs)	Experienced Discharge (cfs)
February 1886	11,000	7,000	14,000*
July 1938	6,300	3,300	6,300
March 1968	6,800	2,700	3,110
SPF	19,000	13,000	-

*Scituate Reservoir not in existence

composite frequency curve was fitted to the plotted data as shown on plate 7.

c. South Branch. A discharge frequency curve for the South Branch at Washington, Rhode Island was developed by statistical analysis using the annual peak flows for 33 years of record, plus the addition of the estimated peak flows for the 1936 through 1938 water years. Thus the analysis was made using 36 annual peak flows. A Log Pearson type analysis was made in accordance with procedures presented in "Statistical Methods in Hydrology" by L. Beard dated January 1962. The basic statistical data is listed in table 9.

d. Locals. The peak discharge frequency curves for the unmodified 50.5 square mile local downstream of Flat River and Scituate Reservoirs and the 30.4 square mile local downstream of the gage were developed by relating the computed 1968 flood contributions from the areas with similar gaged watersheds, namely Kettle Brook and Branch River in the neighboring Blackstone River basin. Statistical data developed for the gaged streams and that adopted for the local watersheds are listed in table 9. The adopted discharge frequency curve for the Pawtuxet River at Cranston is shown on plate 7.

e. Flood stage frequencies. Flood stage-frequency curves, for use in damage-benefit analyses, were developed at various index stations using the discharge frequency information just discussed in conjunction

TABLE 9

DISCHARGE FREQUENCY DATA

	South Branch Pawtuxet River Washington, R.I.	Branch River Blackstone Basin Forestdale, R.I.	Kettle Brook Blackstone Basin Worcester, Mass.	Adopted for Local To Cranston Gage	Adopted for Local Below Cranston
Drainage Area (sq. mi.)	63.8	91.2	31.3	50.5	30.4
Log of Mean	2.81	3.19	2.65	3.05	2.82
Standard Deviation	0.216	0.220	0.325	0.270	0.250
Adopted Skew	+0.5	+0.5	+0.5	+0.50	+0.50
100-Year Frequency (Q in cfs)	2,750	6,600	3,620	6,000	3,000
50-Year Frequency "	2,200	5,300	2,690	4,600	2,500
20-Year Frequency "	1,600	3,950	1,790	3,300	1,800
10-Year Frequency "	1,300	3,100	1,270	2,500	1,400
5-Year Frequency "	950	2,400	850	1,800	1,050
2-Year Frequency "	620	1,480	420	1,100	640

with developed stage-discharge rating curves. The rating curves were developed from backwater studies which are discussed under section 9, entitled, Flood Profiles. In the reach of the river affected by flood tides, composite stage frequency curves were developed reflecting tide and fresh water flooding. For example if a given flood level was expected to be reached 10 times in 100 years by fresh water flooding and 5 times per 100 years by flood tides then the composite curve would indicate flooding to this level 15 times per 100 years.

Modified stage frequency curves for various plans of improvement were similarly developed using the modified discharge frequencies and appropriate rating curves.

f. Effect of future urbanization. In allowing for future development in the watershed it was estimated that flood discharge frequencies would increase 10 percent between the present and 1990 and another 10 percent between 1990 and 2020. Such an estimate cannot be precise but was based on interrelations in New England between population density and land use, land use and percent impervious cover, and percent change in impervious cover and percent change in peak runoff. A Treatise on this subject entitled, "Effect of Urbanization on Peak Runoff" was prepared by the New England Division in June 1973 in connection with a South Eastern New England regional study. Reference is also made to "Effects of Watershed Changes on Streamflow," Water Resources Symposium No. 2, University of Texas Press, 1969.

Population projections for the region were developed in 1972 by the Bureau of Economic Analysis of the U.S. Department of Commerce. Based on this data it is projected that the population density in the Pawtuxet basin will increase from 315 per square mile in 1970 to 540 per square mile in 1990. This growth is expected to result in a 50 percent increase in impervious cover from about 8 to 12 percent and result in a 10 percent increase in peak discharge. At least a comparable percent increase is expected between 1990 and 2020.

8. STANDARD PROJECT FLOOD

a. General. The standard project flood (SPF) represents the flood discharge that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the region, excluding extremely rare combinations. The SPF represents a "standard" against which the flood potential of a river can be judged, as contrasted to an analysis of flood records which may be misleading due to abnormal sequences of events during the period of record. The SPF for the Pawtuxet River was developed using standard project storm rainfall, as described in EM 1110-2-1411, and unit hydrographs derived from analysis of recorded floods in the basin.

b. Rainfall. The standard project storm was oriented over the Pawtuxet watershed with its center near the junction of the two branches with its long axis running in a southwest to northeast direction. The storm pattern is shown on plate 8.

The standard project storm index rainfall for 24 hours over a 200 square mile area is 11 inches. A summary of the adopted standrad project storm contribution for a drainage area of 200 square miles is as follows:

	Inches
SPS Rainfall (24 hrs)	11.0
Losses	2.3
Rainfall Excess	8.7
Maximum 3-Hour Rainfall Excess	5.3

Losses were assumed at the rate of 0.1 inch per hour which is consistant with minimum losses determined in previous Corps of Engineer studies for the New England area. The rainfall over each tributary and local area was obtained by planimetering between the isohyets and respective watershed divides.

c. Unit hydrographs. Unit hydrographs were derived, through analysis of the March 1968 flood, for the watersheds of (1) Flat River Reservoir, (2) Scituate Reservoir and (3) the two downstream local areas. The peaks of all developed unit hydrographs were increased 25 percent, in accordance with EM 1110-2-1405, to reflect the increased runoff rates expected under standard project storm conditions. A typical unit hydrograph development is shown on plate 5.

d. Standard project flood. Rainfall excess was computed for each subwatershed and applied to the adopted unit hydrographs. The resulting hydrographs for Flat River and Scituate Reservoirs were routed through surcharge storage assuming the reservoirs initially filled to spillway crest. The resulting outflow hydrographs were then routed downstream and combined with the component hydrographs from the local areas. The development of the SPF for the Pawtuxet basin is graphically illustrated on plate 8.

9. FLOOD PROFILES

Flood profiles for the mainstem of the Pawtuxet River are shown on plate 2. Profiles were computed by standard backwater procedures using a minimum of surveyed cross sections of the river and the computer program,HEC-2, developed by the Hydrologic Engineering Center in Davis, California. The computer model was calibrated, to the extent possible, against historic flood elevations. In many instances the computed profile for a historic flood discharge was somewhat higher than observed and this was attributed largely to reduced hydraulic capacity of the river due to accelerated development. Backwater computations were made for a range of both natural and modified floods using a Manning's n of 0.05 for channel and 0.08 for overbank. Assumed contraction and expansion loss coefficients were 0.3 and 0.5, respectively.

10. NATICK DIVERSION

a. General. The Natick Diversion, as part of a flood system for

the main stem Pawtuxet River, would divert floodflows from the Pawtuxet River at Natick (river mile 9.75) via deep rock tunnel to Apponaug Cove, a distance of about 13,000 feet. Plans and profiles of the diversion structures are shown on plates 9 through 12. Hydrologic engineering features of the various components of the proposed diversion are discussed in the following paragraphs. Hydraulic analysis made during plan formulation was general in scope. More detailed analysis, probably including model studies of some of the more complex hydraulic structures, will be required in final design.

b. <u>Diversion tunnel</u>. The tunnel will be 30 feet in diameter and approximately 13,000 feet long. Depending on quality of rock the tunnel will be either concrete-lined or smooth-bore unlined with a hydraulic roughness comparable to concrete. The invert of the tunnel at the upstream end will be -75 feet msl and will slope at 0.0104 feet per foot to elevation -210 feet msl at the outlet. With the design discharge of 13,000 cfs the velocity of flow in the tunnel will be 18 feet per second. The hydraulic capacity of the tunnel was computed using a Manning's "n" of 0.015.

c. <u>Diversion inlet</u>. The inlet to the tunnel will be a "morning glory" type spillway atop a [illegible]0-foot diameter vertical shaft. The inlet will be located in the Pawtuxet River just downstream of the existing Natick dam. The lip of the morning glory with a circumference of 121.9 feet will be at elevation 38 feet msl approximately 10 feet above the existing riverbed. Regulation

of flows to the diversion will be accomplished by the construction of a regulating dam just downstream of the inlet. This dam will contain two 8x8 foot regulating gates and a 115 foot long emergency overflow weir at elevation 48.0 feet msl. The gated outlets will permit passage of normal riverflows. Closing the gates will cause the water rise and enter the inlet to the diversion tunnel. Throttling the gates will allow the diversion to be self regulating for Pawtuxet River flood control. The lip of the morning glory spillway will be a hydrualic control for flows up to approximately 12,000 cfs, with a required head pool elevation at the inlet of about 43.5 feet msl. With flows greater then approximately 12,000 cfs the inlet will become submerged by tunnel backwater and the hydraulic control will switch to the tunnel outlet. With the head pool at elevation 48 feet msl, the diversion will be capable of discharging 13,000 cfs for all tides up to about +10 feet msl. Approximately 11,000 cfs could be diverted with a tide as high as 20 feet above msl. Plans of the inlet are shown on plates 10 through 12.

d. Diversion outlet. The outlet of the diversion tunnel will consist of a 30-foot diameter vertical shaft transitioning to a 114-foot long horizontal apron. A plan and profile of the outlet is shown on plates 11 and 12. The outlet end sill will be at elevation -4 feet msl and equipped with stop log piers to permit evacuation of the tunnel if necessary. Under design discharge conditions, and for all

tides below approximately +10 feet msl, the 90-foot clear span between the piers on the end sill will be the hydraulic control. Flows exiting the outlet are directed away from shore towards the existing Federal navigation channel. An apron of riprap will be placed at the outlet exit to prevent excessive scour from diversion during periods of low tide. With a design flow of 13,000 cfs the velocity in the vertical shaft will be approximately 18 feet per second. Water surface at the top of the shaft would rise to near the energy gradient of +10.0 feet msl and then drop to about critical depth elevation of +6 feet msl through the piers on the outlet sill. Critical depth and velocities through the piers on the end sill, with a flow of 13,000 would be approximately 9 feet and 18 feet per second, respectively. Head loss through the outlet structure, including one velocity head, was estimated to be approximately 7 feet.

e. Apponaug Cove. Outlet discharges from the diversion tunnel will flow through Apponaug Cove a distance of approximately 4,500 feet to the ocean. Hydraulic head loss and velocities through the cove would be a maximum with diversion during low tide. Hydraulic head loss and maximum velocity in the navigation channel through the cove for different tides and diversion rates are listed in table 10.

f. Effects of Diversion. The effects of the Natick diversion on downstream flooding on the Pawtuxet River is summarized in table 11.

TABLE 10

APPONAUG COVE HYDRAULICS

Tide Level (ft msl)	Diversion Rate (cfs)	Head Loss in Cove (ft)	Maximum Velocity in Channel (ft/sec)
Mean low water	13,000	3.0	8.0
-1.9	8,000	1.5	5.5
	3,000	0.4	2.3
Spring tide			
+3.6	13,[illegible]	0.4	4.4
	8,000	0.2	2.7
	3,000	Negligible	1.0
10-year frequency tide			
+8.6	13,000	0.2	2.7
	8,000	Negligible	1.5
	3,000	Negligible	0.[illegible]

TABLE 11

EFFECTS OF NATICK DIVERSION

Location	Drainage Area (sq. mi.)	March 1968 Flood Natural Q (cfs)	March 1968 Flood Natural Elevation (feet msl)	March 1968 Flood Modified Q (cfs)	March 1968 Flood Modified Elevation (feet msl)	July 1938 Flood Natural Q (cfs)	July 1938 Flood Natural Elevation (feet msl)	July 1938 Flood Modified Q (cfs)	July 1938 Flood Modified Elevation (feet msl)
Pawtuxet River at Natick Diversion	180	2,600	33.4	-	28.0	5,800	37.6	-	28.0
At Cranston USGS Gage	200.0	3,110	19.7	800	17.3	6,300	22.7	800	17.3
At Warwick Avenue	228	3,900	12.0	2,000	9.7	6,800	14.3	2,100	9.8

Location	Drainage Area (sq. mi.)	100-Year Frequency Flood Natural Q (cfs)	100-Year Frequency Flood Natural Elevation (feet msl)	100-Year Frequency Flood Modified Q (cfs)	100-Year Frequency Flood Modified Elevation (feet msl)	Standard Project Flood Natural Q (cfs)	Standard Project Flood Natural Elevation (feet msl)	Standard Project Flood Modified Q (cfs)	Standard Project Flood Modified Elevation (feet msl)
At Natick Diversion	180	5,500	37.4	-	30.6	17,000	46.9	4,000	35.4
At Cranston USGS Gage	200.0	6,600	23.0	2,300	20.8	19,600	32.8	4,700	25.6
At Warwick Avenue	228	8,200	15.2	5,400	13.6*	23,000	21.3	12,800	18.6*

*Tidal Flood Level

Flood levels would be generally reduced from 3 to 6 feet and the standard project flood would be reduced generally from 5 to 10 feet. Modified flood profiles are shown on plate 2. Modified flood stages and frequencies downstream of the diversion are a function of (1) hurricane tides, (2) runoff from the downstream uncontrolled watershed area, and (3) some spillage at the diversion during the rarest of floods. The modified profiles were determined by back-water computations using the modified flood discharges.

11. WARWICK LOCAL PROTECTION (Warwick Ave Area)

a. General. As previously discussed, properties on the Pawtuxet River flood plain near the mouth of the river are susceptible to flooding from either abnormal tides in Narraganset Bay or fresh water flows of the river. The Natick diversion will greatly reduce the frequency and magnitude of fresh water flooding but the Warwick Ave Area Local Protection Project is required to protect the Warwick Industrial Park against residual tidal and fresh water flooding. The project consists of about 6,000 linear feet of dikes and walls, 2 street opening structures, approximately 1,000 feet of channel relocation, and two pumping stations for removal of interior drainage. The project will provide protection to approximately 150 acres of industrial and commercial areas.

b. Design Flood Criteria. The dikes and walls were designed to protect against the severest of the following criteria: (a) a modified standard project flood on the river coincident with a 100-year frequency

tide in the bay and (b) a standard project tide in Narraganset Bay. A general plan of the project is shown on Plate 13.

The design tide levels upstream of the Pawtuxet dam were reduced 2 feet from those in Narraganset Bay to reflect the modifying effect of the dam as was discussed in Section 5c. The standard project and 100-year frequency tides in the bay are 20.5 and 16 feet msl, respectively; therefore, comparable levels upstream of the dam are 18.5 and 14 feet msl, respectively. The governing criteria for the dikes and walls were, for the most part, the standard project tide level of 18.5 feet msl. The design flood level for the project varied from 18.5 feet msl at the downstream end of the protection to 22 feet msl at the upstream end. Design flood profiles are shown on plates 14 and 15.

c. Freeboard. Freeboard is defined as the vertical distance measured from the design water surface to the top of dike or wall. Freeboard is provided to ensure that the desired degree of protection will not be reduced by unaccounted factors.

The dikes and concrete walls for the Warwick Ave area local protection were designed to provide 3 and 2 feet of freeboard, respectively. Less freeboard is provided with concrete walls due to their greater resistance to failure if some overtopping were to occur. Building walls slightly lower than the dikes also permit overtopping of walls before dikes; thereby serving as a relief valve in the event of a flood greater than design.

d. Velocities. Maximum flow velocities in the river channel along the line of protection would occur during high flows in the river and normal tides in the bay. Maximum velocities with a modified standard project discharge of 12,800 cfs would range from 5 to 7 feet per second. The riverside slopes of the protective dikes will be protected by riprap designed to withstand the tractive forces that would be produced by the modified design flood.

e. Effect of project on river hydraulics. During flood periods when dishcarges and stages in streams are increasing, those flows entering flood plain areas are temporarily stored until the recession period of the flood. The effect of this temporary storage is, to lag and reduce the flood peak as it progresses downstream. When flood plain storage is lost by the building of dikes, the flows that would normally enter the storage areas must either move into adjoining storage areas or move on through the reach causing increased flood discharges downstream, at least during the rising period of the flood. Historically flood stages on the lower Pawtuxet River have risen at rates up to one-sixth foot per hour. The two local protection projects will remove approximately 200 acres of flood plain, therefore, this rate of rise of water over the protected area would represent a flow rate of 400 cfs. Using the above analogy it was concluded that peak discharges would not be increased more than 5 percent by the dikes and since the diversion will reduce flows by approximately 50 percent in the area of the

dikes, the net effect of both the diversion and local protective dikes would be at least a 45 percent reduction in flows.

f. Interior Drainage.

(1) General. The line of protection of the Warwick Ave area LPP will intercept the runoff from approximately 710 acres of interior area. Gravity outlets, a collector drain, pressure conduit and a pumping station are included as an integral part of the project for conveying interior drainage to the river.

(2) Drainage Areas. The total 710 acres of interior area can best be analyzed as 3 subareas. Subarea 1 is a 110 acre area located upstream of Warwick Avenue extending to the upper end of the project. This area is mostly residential with an average slope of about 2 percent draining to the highly industrial and very flat area lying right along the river. Subarea 2, 150 acres in size, is generally outlined by Warwick Avenue on the west, Boston Post Road on the south and the Pawtuxet River on the northeast. This area is extremely flat having practically no drainage relief. The one existing open channel drain passing through serves much of the area.

Subarea 3, an independent 450 acres of watershed lying south of Boston Post Road, is drained by an unnamed brook and outleting to the Pawtuxet River near the downstream end of the proposed line of protection. Subarea 3 is long and narrow with an average slope of about 0.6 percent. There are two natural ponds in the upper part of this watershed which serve to retard runoff from short duration high intensity storms.

Delineation of the subareas is shown on plate 13 .

Estimated 10- and 100-year frequency discharges for the subareas are listed below. Discharge values were computed by multiplying the discharge frequencies developed for the entire local area below the Cranston gage by the ratio of contributing drainage area taken to the 0.7 power. The computed discharge frequencies compared favorably with results obtained using methods presented in: "Flood Magnitude and Frequency of Massachusetts Streams," Open-File Report Number 84-131, U.S. Department of the Interior, Geological Survey, March 1974.

	Subarea 1	Subarea 2	Subarea 3
Drainage Area (acres)	110	150	450
10 Year Q (cfs)	37	46	100
100 Year Q (cfs)	80	100	214

It is noted that the discharge frequencies represent estimated runoff from a watershed with widespread shallow puddling during intense rainfall. This condition currently exists and will presumably exist in the future due to the minimal drainage relief in the area. This shallow ponding will be restricted to parking lots and undeveloped areas in the future through proper zoning.

(3) Site limitations. The elevation of most of the land along the land side of the dikes and walls is very low relative to

the normal level of the Pawtuxet River. The normal level of the river is about +5 feet msl and most of the land is between elevations 8 and 10 feet msl. This site limitation makes impractical the installation of large underground collector drains. Such drains would remain filled with water without continuous and costly pumping. For this reason it is planned to provide a shallow trapezoidal channel section along the land side of the dike which will serve both as a temporary detention area and a means of conveying flows to one centrally located pumping station. It will be specified in the local assurances that no building be allowed in the protected area with first floor grades below elevation 12.0 feet msl.

(4) Gravity outlets. Gravity outlets will be provided through the line of protection capable of discharging the peak 100-year frequency runoff with a normal river stage.

(5) Warwick Ave Area pumping Station #1. Warwick pumping station #1 will be designed to discharge the 10-year frequency interior runoff against a design river stage. The pumping station will have a design capacity of 80 cfs, the 10-year peak runoff from subareas 1 and 2.

(6) Warwick Ave Area pumping station #2. Subarea 3 will normally discharge by gravity to the river through a gated outlet in the line of protection at a site near its present outlet. However, pumping station #2 will be provided at the site so that during hurricant tides the

gravity outlet can be closed and the interior runoff can be pumped. The gravity outlet will be designed to discharge the 100-year frequency discharge of 210 cfs with a normal river stage. Pumping station #2 will be designed with a 10-year frequency peak runoff capacity of 100 cfs.

A pressure conduit system in lieu of a pumping station for subarea 3 was investigated but was found to provide small savings in cost. *Further interior drainage analysis will be performed during* detailed design.

12. WARWICK LOCAL PROTECTION (Elmwood Ave Area)

a. General. The Elmwood Ave Area Local Protection Project will be built to protect approximately 43 acres of mostly residential property from residual Pawtuxet River flooding. The project will consist of about 4,700 linear feet of dike, 400 feet of wall, and interior drainage facilities including one pumping station. A plan of the project is shown on plate 16.

b. Design Flood. The project will be designed to provide three feet of freeboard above the standard project flood level of the Pawtuxet River as modified by the proposed upstream Natick diversion. Height of protection will vary from elevation 26 feet mean sea level at the downstream end of the dike to elevation 27 feet mean sea level at the upstream end. Design profiles are shown on plate 17. The modified

SPF discharge at the project site is 12,000 cfs.

c. Velocities. Maximum velocities in the river channel along the line of protection with a modified SPF discharge would range from three to five feet per second. The riverside slopes of the protective dikes will be protected by rip rap designed to withstand the tractive forces produced by the design flood.

d. Effects of Project on River Hydraulics. For information on the effects of the Elmwood Ave area project on the hydraulics of the Pawtuxet River, reference is made to paragraph 11e.

e. Interior Drainage. The dikes and walls at the Elmwood Ave Area LPP will intercept runoff from a total of approximately 150 acres of interior area. No detailed analysis was made for interior drainage, but for costing purposes it was assumed that drainage from the upper 85 acres of area lying south of 2nd Avenue would be discharged to the river through a 48-inch diameter pressure conduit, and a pumping station would be provided for the remaining lower 65 acres of interior area. The pumping station and pressure conduit were designed to pass a 10 year storm runoff against the design river stage, resulting in design capacities of 105 and 135 cfs, respectively. Gravity drains through the dike were designed to discharge the 100 year storm runoff with a normal river stage. Discharges were computed using the Rational formula with a coefficient of 0.5 and a time of concentration of 30 minutes. More detailed analysis of interior drainage will be required during final design.

13. PAWTUXET RIVER WATER QUALITY

The Pawtuxet River is an intrastate stream that has been assigned a B classification by the state of Rhode Island. State prescribed standards for Class B water designate that it shall have good aesthetic quality and that it be suitable for water supply with appropriate treatment, waterborne recreation, fish and wildlife habitat, agricultural usages, industrial processes and cooling.

Class B water quality standards require that the dissolved oxygen concentration be a minimum of 5 mg/l at any time and at least 75 percent saturated for 16 hours/day. Coliform bacteria are not to exceed a median value of 1,000 colonies/100 ml nor more than 2,400 in more than 20 percent of the samples collected. These waters are also to be free from concentrations of chemical constituents and radioactive material which would be harmful to human, animal or aquatic life. The pH range is always to be within 6.5 to 8.0 standard units and any increases in temperature, color, turbidity, taste and odor will be such that they will not impair any of the above mentioned usages.

The quality of water for a prescribed distance downstream from waste treatment facilities, until complete mixing is accomplished, does not affect the usage class adopted.

The New England Division initiated a water quality sampling program in the Pawtuxet River basin during September 1975. The purspose

of the program was to develop a data base with which to evaluate the water quality effects of the proposed diversion of flood waters from the Pawtuxet River on the marine environment of Apponaug Cove and Greenwich Bay, Rhode Island. Two sampling stations were located on the main stream Pawtuxet River and one each on the North Branch and South Branch tributaries. Collection and analysis of the samples was performed for the Corps by the U.S. Environmental Protection Agency laboratories in Kingston, Rhode Island and Needham, Massachusetts. The water quality data for each of the stations are presented on tables 12 through 15.

Evaluation of these data indicates that the quality of water measured during the nine month sampling program does not meet the prescribed state stream standards. However, it is expected that implementation of the State of Rhode Island's pollution abatement program will produce acceptable water quality levels by 1983, as required by federal Public Law 92-500.

TABLE 12

PAWTUXET RIVER
WATER QUALITY DATA
STATION 1: BROAD STREET, CRANSTON

Date	Average Daily Flow* (cfs)	Air Temp. (°C)	Water Temp. (°C)	pH (su)	pH Paper	Dissolved Oxygen (mg/l)	Total Coliform Bacteria (/100 ml)	Fecal Coliform Bacteria (/100 ml)	NH_3-N (mg/l)	COD (mg/l)	Total Nonflt. Residue (mg/l)	Volatile Nonfiltr. Residue (mg/l)	Fixed Nonfiltr. Residue (mg/l)	BOD 5-Day (mg/l)	BOD 20-Day (mg/l)
(1975) 16 Sep	137	19	18	6.0	6.0	7.0	92,000	1,700	2.00	37	8	4	4	J12.8**	22.3**
25 Sep	679	11	16	5.7	-	-	70,000	3,300	0.40					6.6**	12.4**
2 Oct	263	19.5	18.5	6.9	-	7.7	5,400	1,700	1.15	28	9	6	2	J5.9	15.4**
30 Oct	335	16	14	6.9		9.0	92,000	54,000	K0.10	24	3	3	K1	5.2	6.6**
18 Nov	506	17	11	7.0	-	9.2	1,700	460	0.65	27	5	4	2	J5.5	10.3**
9 Dec	570	-	-	-	-	-	9,200	330	0.45	22	5	4	1	J4.5	9.2
(1976) 20 Jan	854	-1	3	7.5		13.8	5,400	270	0.45	16	1	1	K1	J2**	J6
2 Feb	1690	1.7	4	7.35		14.0	24,000	7,900						-	-
24 Feb	774	10	6	7.6		12.3	13,000	170	0.46	20	4	2	2	J6	11.5**
29 Mar	295	15.0	10.0	6.3		10.6	26,000	260							
28 Apr	297						9,400	1,300							
27 May	217	22	14.5	6.1			1,300	130							
7 Jun	no record	28	17.5	7.05			1,300	330							

*Average daily flow at Cranston Gage, Pawtuxet River (PROVISIONAL)
**Average of two values
K = less than J = estimated

TABLE 13

PAWTUXET RIVER
WATER QUALITY DATA
STATION 2: PROVIDENCE STREET, WEST WARWICK

Date	Average Daily Flow* (cfs)	Air Temp. (°C)	Water Temp. (°C)	pH (su)	pH Paper	Dissolved Oxygen (mg/l)	Total Coliform Bacteria (/100 ml)	Fecal Coliform Bacteria (/100 ml)	NH_3-N (mg/l)	COD (mg/l)	Total Nonfltr. Residue (mg/l)	Volatile Nonfiltr. Residue (mg/l)	Fixed Nonfiltr. Residue (mg/l)	BOD 5-Day (mg/l)	BOD 20-Day (mg/l)
(1975)															
16 Sep	137	19	18	6.3	6.0	7.7	>160,000	2,600	0.80	17	10	3	7	J3.5	5.5**
25 Sep	679	11	15	6.7	-	-	49,000	7,900	0.15					5.5**	8.4**
2 Oct	263	20	13.5	6.9	-	7.7	35,000	4,600	0.25	19	3	2	1	J1.8	6.6**
30 Oct	335	16	15	6.8		8.2	>240,000	35,000	K0.10	58	6	4	1	29.8**	39.6**
18 Nov	506	17	11	7.4		9.0	35,000	1,300	0.07	18	3	2	K1	J1.8	3.9**
9 Dec	570	-	-	-		-	3,500	490	K0.05	10	2	2	K1	J2.	4.1**
(1976)															
20 Jan	854	-1.	3.2	5.25		13.8	3,500	1,100	K0.05	15	27	4	23	J2**	J4
2 Feb	1,690	0.6	3.0	6.8		14.0	92,000	7,000						-	-
24 Feb	774	10.	5.	7.65		12.2	2,400	790	0.14	9	2	1	1	J1.8	4.5**
29 Mar	295	16.0	10.2	6.7		11.0	35,000	4,900							
28 Apr	297						14,000	7,000							
27 May	217	21.	14.5	6.5			6,400	2,700							
[illegible] Jun	no record	27.5	17.5	6.7			9,400	[illegible],700							

*Average daily flow at Cranston Gage, Pawtuxet River (PROVISIONAL)
**Average of two values
K = less than J = estimated

TABLE 14

PAWTUXET RIVER
WATER QUALITY DATA
STATION 3: ROUTE 33, WEST WARWICK
SOUTH BRANCH, PAWTUXET RIVER

Date	Average Daily Flow* (cfs)	Air Temp. (°C)	Water Temp. (°C)	pH (su)	pH Paper	Dissolved Oxygen (mg/l)	Total Coliform Bacteria (/100 ml)	Fecal Coliform Bacteria (/100 ml)	NH_3-N (mg/l)	COD (mg/l)	Total Nonfiltr. Residue (mg/l)	Volatile Nonfiltr. Residue (mg/l)	Fixed Nonfiltr. Residue (mg/l)	BOD 5-Day (mg/l)	BOD 20-Day (mg/l)
(1975)															
16 Sep	137	19	17.5	5.95	6.0	8.8	35,000	4,900	0.70	31	6	4	3	J15.9**	20.9**
25 Sep	679	11	15.0	6.4	-	-	230,000	49,000	0.20					3.9	8.0**
2 Oct	263	19	19	6.4	-	6.6	>160,000	>160,000	0.25	46	3	2	1	J16.2**	24.0**
30 Oct	335	16	15	7.5		8.5	13,000	13,000	K0.10	27	10	6	4	12.2	15.2**
18 Nov	506	17	11	7.2		12.1	23,000	7,000	0.08	37	4	3	K1	J9.9**	15.3**
9 Dec	570	-	-	-		-	22,000	4,900	0.05	39	4	4	K1	J10.5**	14.2**
(1976)															
20 Jan	854	-1.	3.2	5.2		13.8	9,200	700	0.06	27	2	2	1	J11.5**	J16
2 Feb	1,690	-0.6	3.0	7.5		16.0	350,000	9,400						-	-
24 Feb	774	10.0	6.0	6.5		11.0	280,000	620	0.26	27	2	1	1	J9.8	16**
29 Mar	295	16.0	10.0	6.9		10.4	540,000	49,000							
28 Apr	297						160,000	13,000							
27 May	217	20.	16.0	6.3			54,000	17,000							
7 Jun	no record	27.	17.	.95			11,000	1,300							

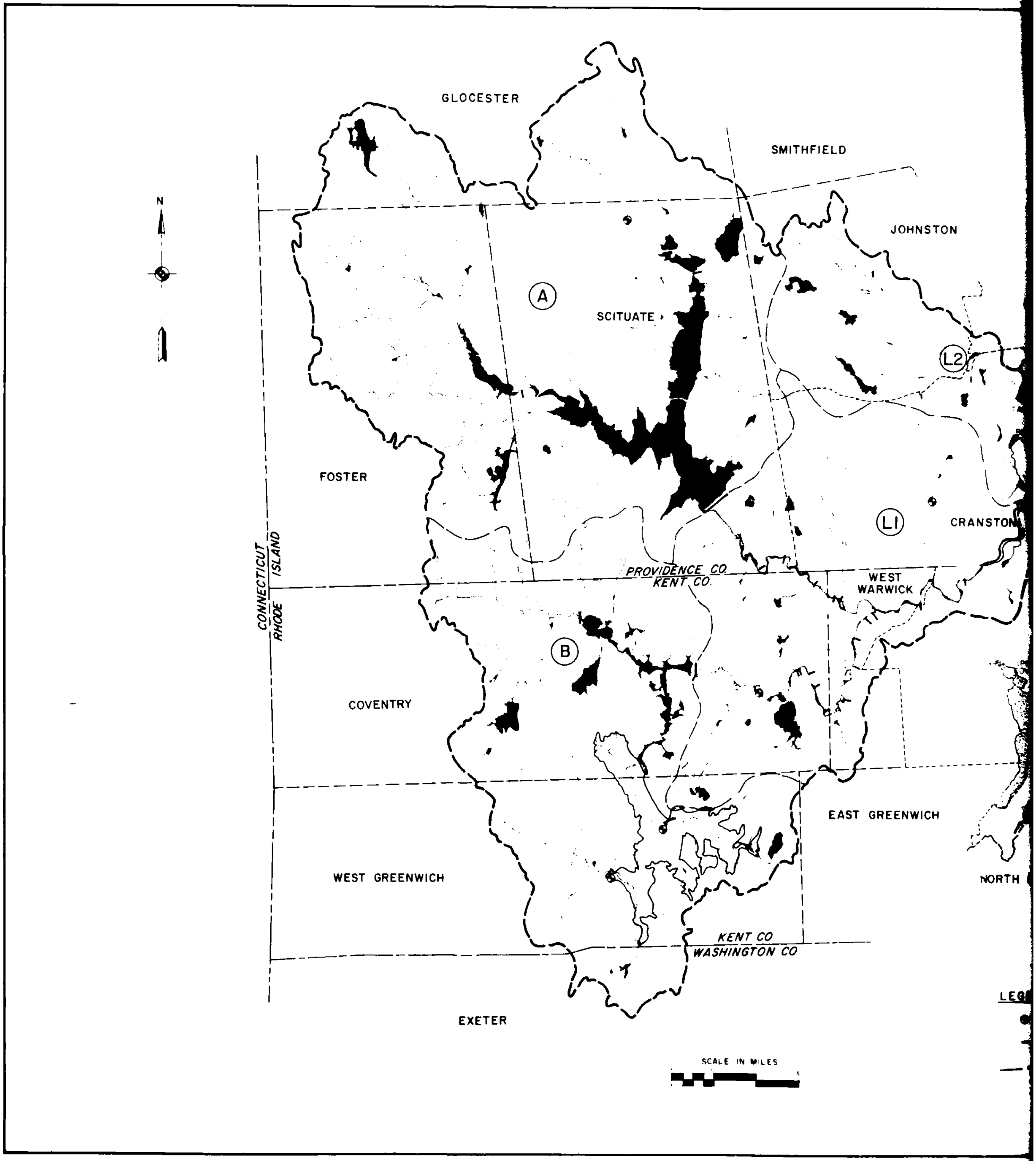
*Average daily flow at Cranston Gage, Pawtuxet River (PROVISIONAL)
**Averate of two values
K = less than J = estimated

TABLE 15

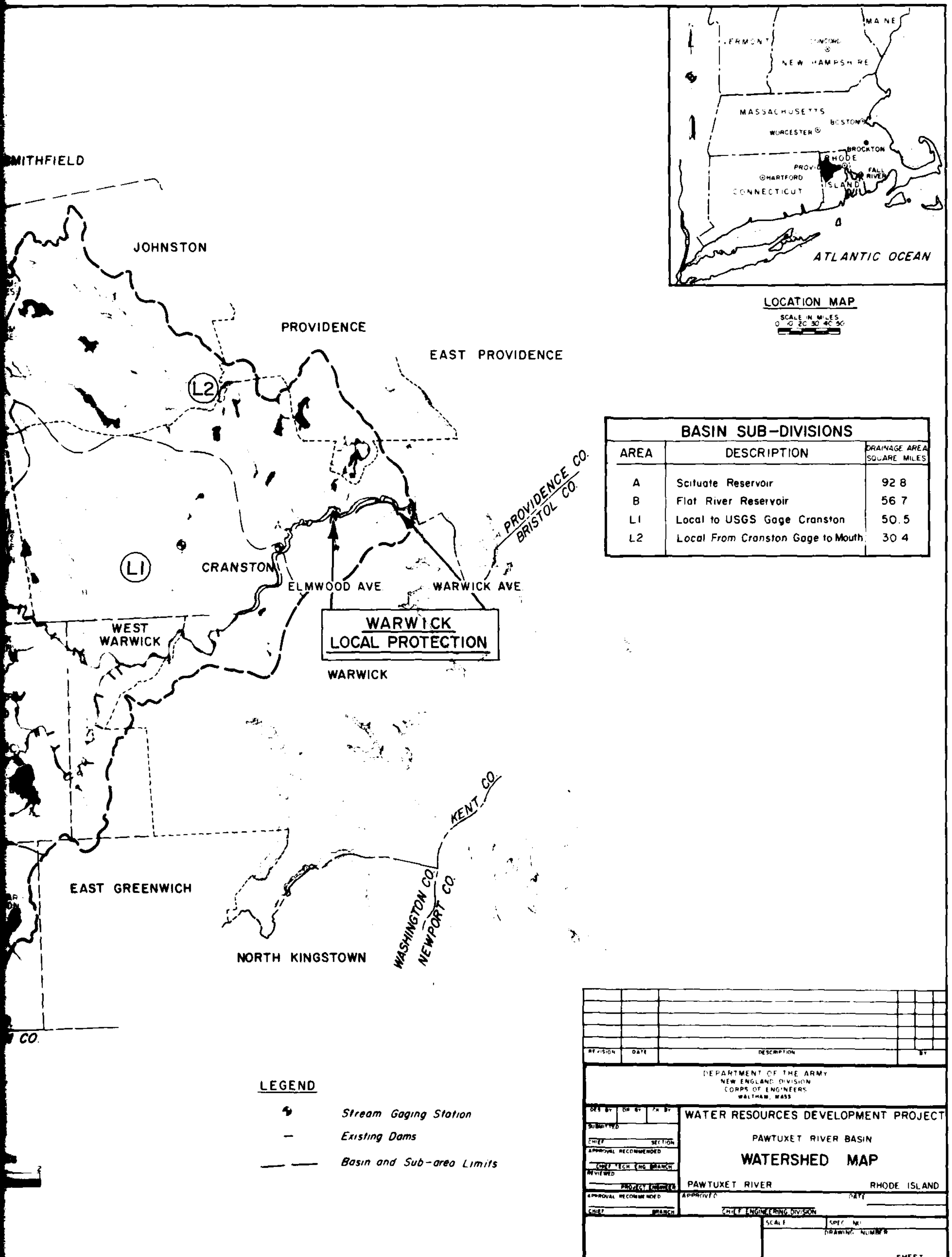
PAWTUXET RIVER
WATER QUALITY DATA
STATION 4: ROUTE 115, WEST WARWICK
NORTH BRANCH, PAWTUXET RIVER

Date	Average Daily Flow* (cfs)	Air Temp. (°C)	Water Temp. (°C)	pH (su)	pH Paper	Dissolved Oxygen (mg/l)	Total Coliform Bacteria (/100 ml)	Fecal Coliform Bacteria (/100 ml)	NH_3-N (mg/l)	COD (mg/l)	Total Nonfiltr. Residue (mg/l)	Volatile Nonfiltr. Residue (mg/l)	Fixed Nonfiltr. Residue (mg/l)	BOD 5-Day (mg/l)	BOD 20-Day (mg/l)
(1975) 16 Sep	137	19.5	18	6.0	6.5	9.0	160,000	3,900	0.6	5	6	1	4	J1.6	3.8**
25 Sep	679	11.0	15.5	6.6	-	-	49,000	2,300	0.90					5.1	8.6**
2 Oct	263	20	18	6.7	-	9.2	5,400	490	K0.10	10	1	1	K1	J2.3	4.3**
30 Oct	335	16	15	6.9		9.9	35,000	4,600	J0.85	34	10	5	5	3.8**	7.1**
13 Nov	506	17	14	7.0		8.1	17,000	13,000	0.30	14	K1	K1	K1	J3.6	5.8**
9 Dec	570	-	-	-		-	9,200	790	0.05	12	12	6	6	J2.0	3.5**
(1976) 20 Jan	354	-1	3.25	7.6		13.2	9,200	5,400	0.38	14	1	1	K1	J2.5**	J4
2 Feb	1,690	-0.6	3.0	7.2		14.0	1,300	1,300						-	-
24 Feb	774	10.0	5.0	7.45		12.9	400	140	0.17	9	2	2	K1	J1.8	J4**
29 Mar	295	15.0	9.5	7.2		10.6	3,500	1,700							
28 Apr	297						7,900	1,700							
27 May	217	20.	15	6.35			16,000	790							
7 Jun	no record	27.0	18	6.4			3,300	330							

*Average daily flow at Cranston Gage, Pawtuxet River (PROVISIONAL)
**Average of two values
K = less than J = estimated



GLOCESTER
SMITHFIELD
JOHNSTON
N
A
SCITUATE
L2
FOSTER
L1
CRANSTON
CONNECTICUT
RHODE ISLAND
PROVIDENCE CO.
KENT CO.
WEST WARWICK
B
COVENTRY
EAST GREENWICH
WEST GREENWICH
NORTH
KENT CO.
WASHINGTON CO.
EXETER
SCALE IN MILES



BASIN SUB-DIVISIONS

AREA	DESCRIPTION	DRAINAGE AREA SQUARE MILES
A	Scituate Reservoir	92.8
B	Flat River Reservoir	56.7
L1	Local to USGS Gage Cranston	50.5
L2	Local From Cranston Gage to Mouth	30.4

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

WATER RESOURCES DEVELOPMENT PROJECT

PAWTUXET RIVER BASIN

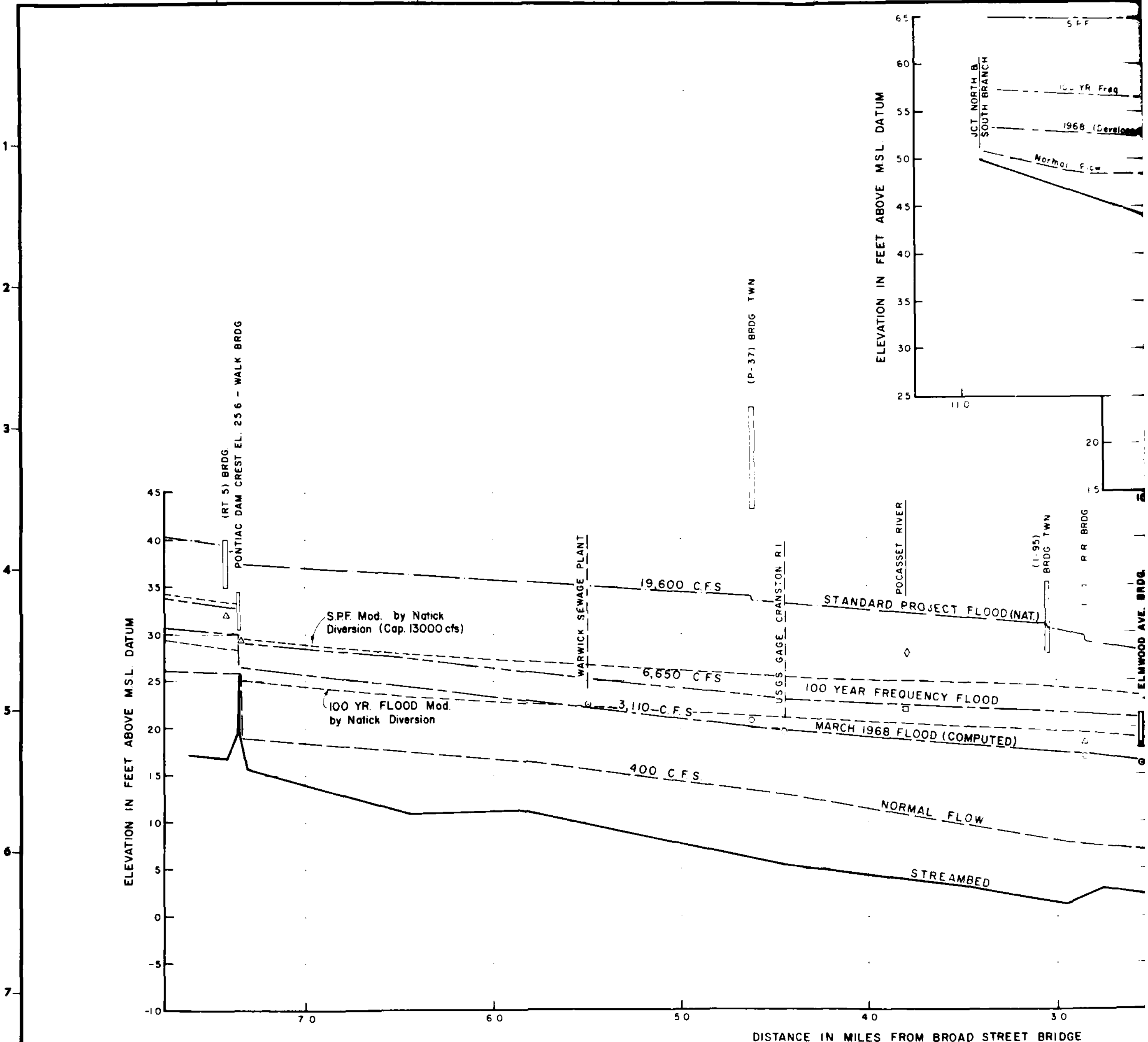
WATERSHED MAP

PAWTUXET RIVER RHODE ISLAND

DES BY / DR BY / CH BY / SUBMITTED / CHIEF SECTION / APPROVAL RECOMMENDED / CHIEF TECH ENG BRANCH / REVIEWED / PROJECT ENGINEER / APPROVAL RECOMMENDED / CHIEF BRANCH / APPROVED / DATE / CHIEF ENGINEERING DIVISION / SCALE / SPEC NO / DRAWING NUMBER / SHEET

PLATE 1

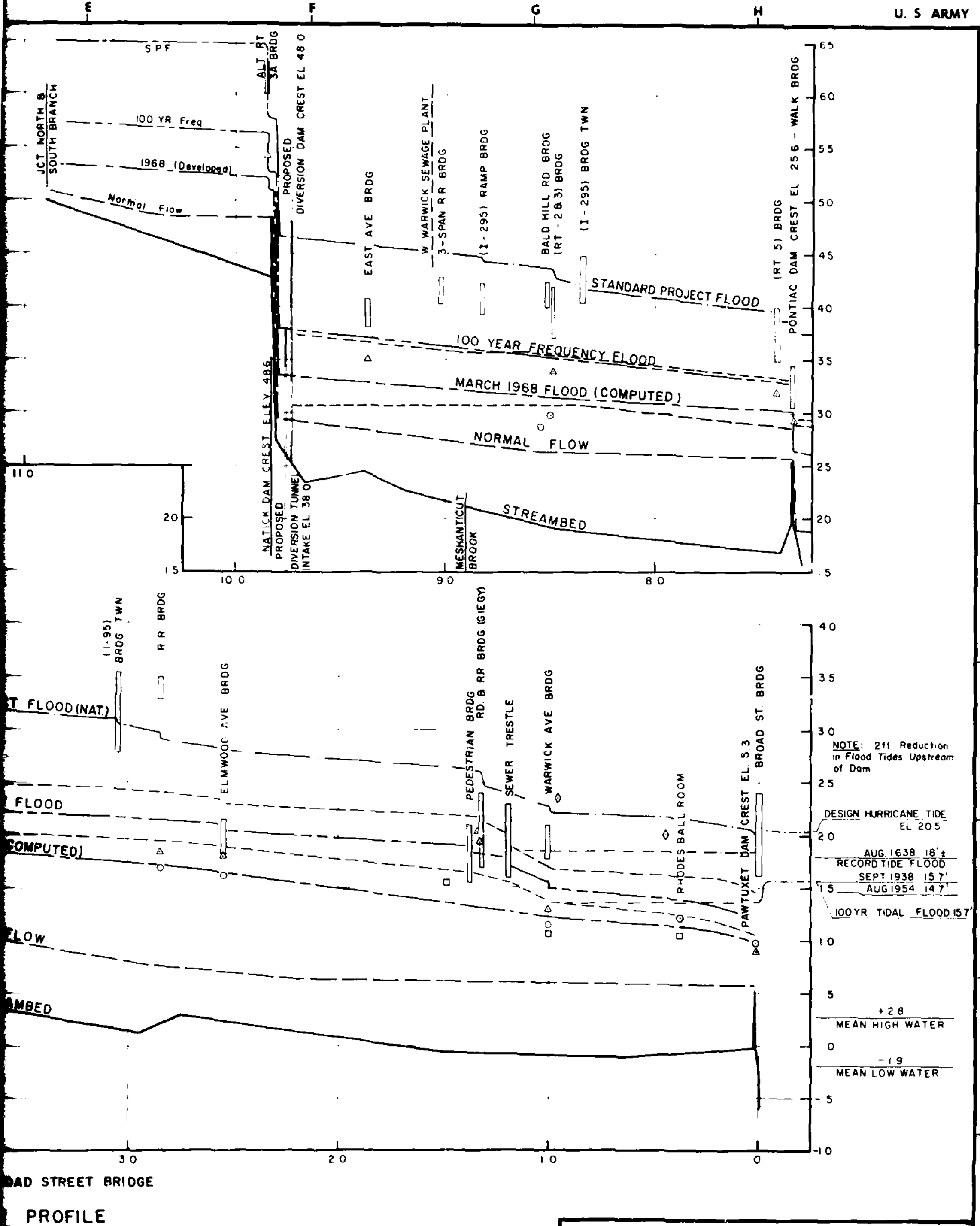
CORPS OF ENGINEERS



PAWTUXET RIVER PROFILE

LEGEND:

- △ INDICATES H.W.M. JULY 1938
- ⊙ INDICATES H.W.M. MARCH 1968
- ⊡ INDICATES H.W.M. MARCH 1936
- ◊ INDICATES H.W.M. FEB. 1886



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT

PAWTUXET RIVER BASIN

MAIN STEM

FLOOD PROFILES

PAWTUXET RIVER — RHODE ISLAND

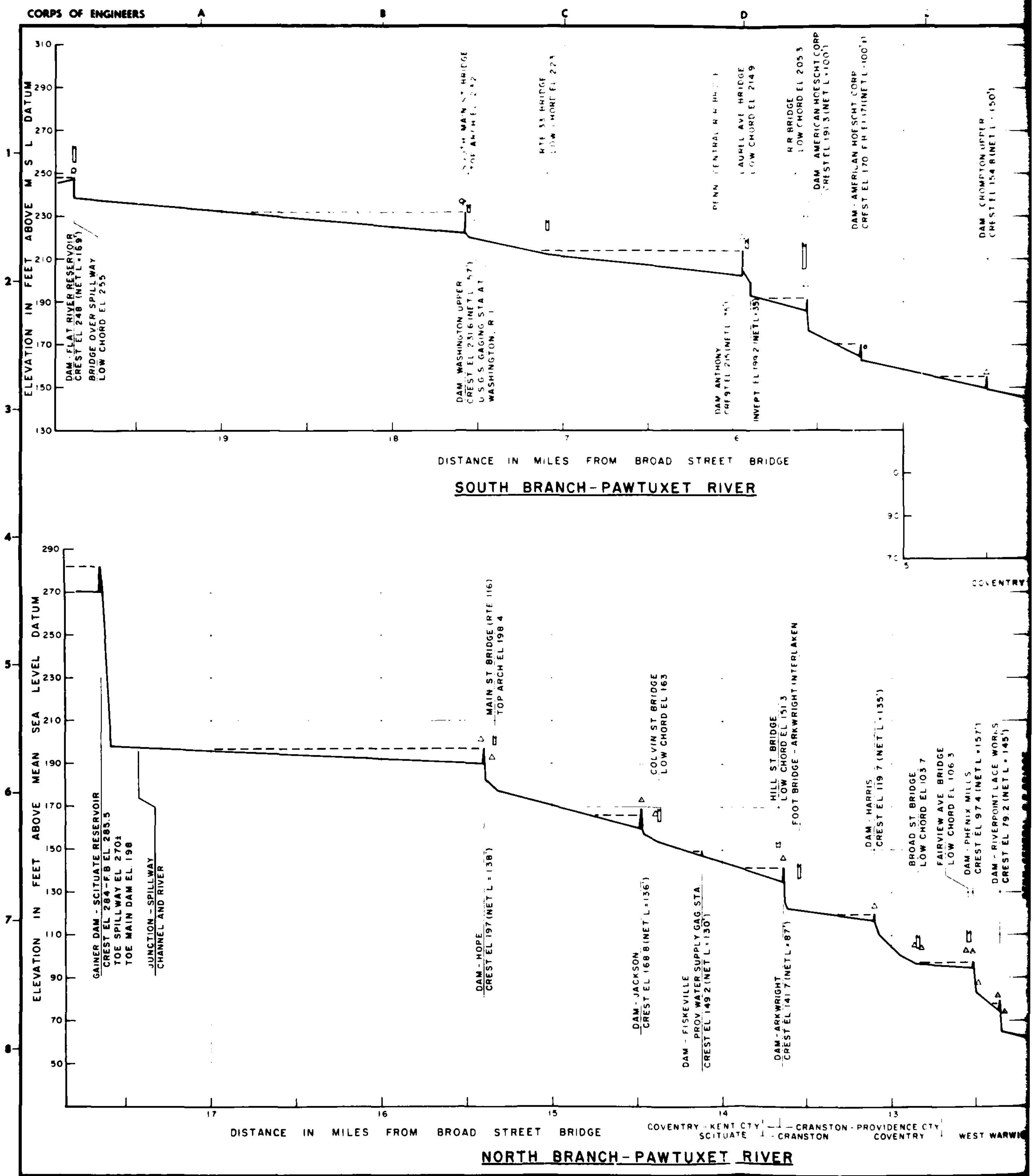
DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF, BRANCH
APPROVED — DATE
CHIEF, ENGINEERING DIVISION
SCALE — SPEC NO
DRAWING NUMBER
SHEET

PLATE 2

AD-A105 823 CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV F/G 13/2
BIG RIVER RESERVOIR PROJECT - PAWCATUCK RIVER AND NARRAGANSETT --ETC(U)
JUL 81

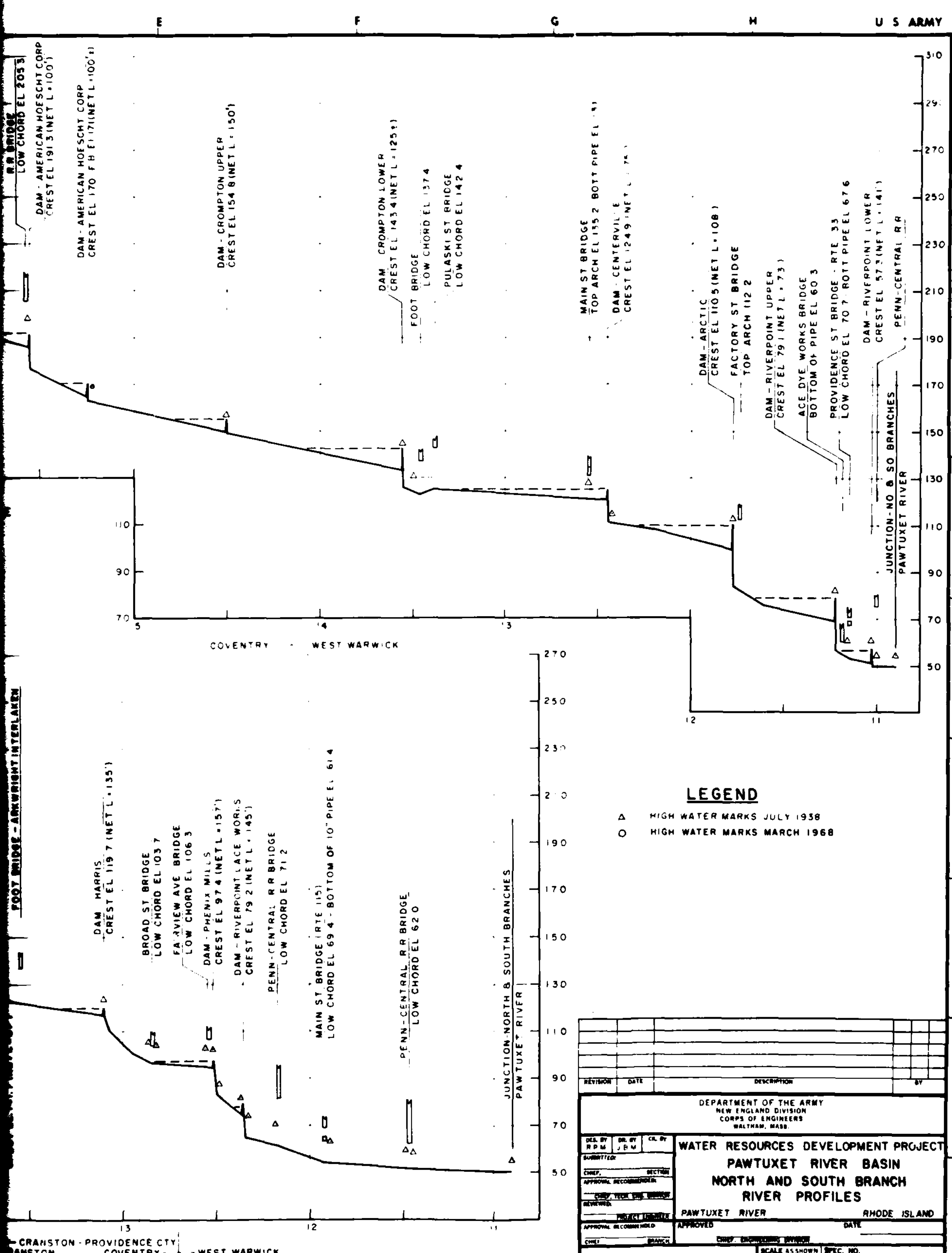
UNCLASSIFIED NL

8 OF 9
AD A
105823



SOUTH BRANCH-PAWTUXET RIVER

NORTH BRANCH-PAWTUXET RIVER



LEGEND

△ HIGH WATER MARKS JULY 1938

○ HIGH WATER MARKS MARCH 1968

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY R P M | DR. BY J B M | CK. BY

SUBMITTED: CHIEF, SECTION
APPROVAL RECOMMENDED: CHIEF, TECH. ENG. DIVISION
REVIEWED: PROJECT ENGINEER
APPROVAL RECOMMENDED: CHIEF, BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
NORTH AND SOUTH BRANCH
RIVER PROFILES

PAWTUXET RIVER — RHODE ISLAND

APPROVED: CHIEF, ENGINEERING DIVISION — DATE

SCALE AS SHOWN | SPEC. NO. | DRAWING NUMBER | SHEET

PLATE 3

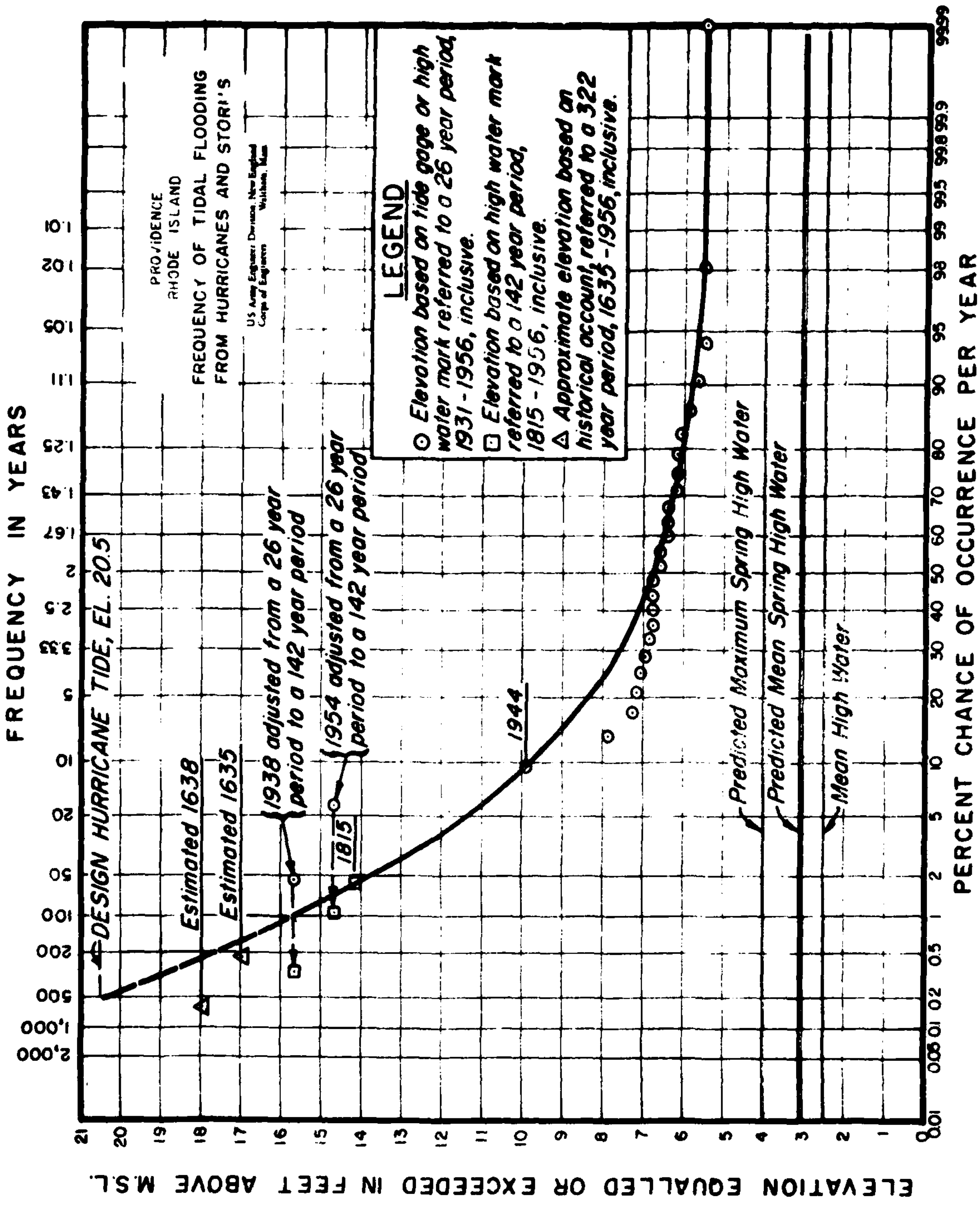
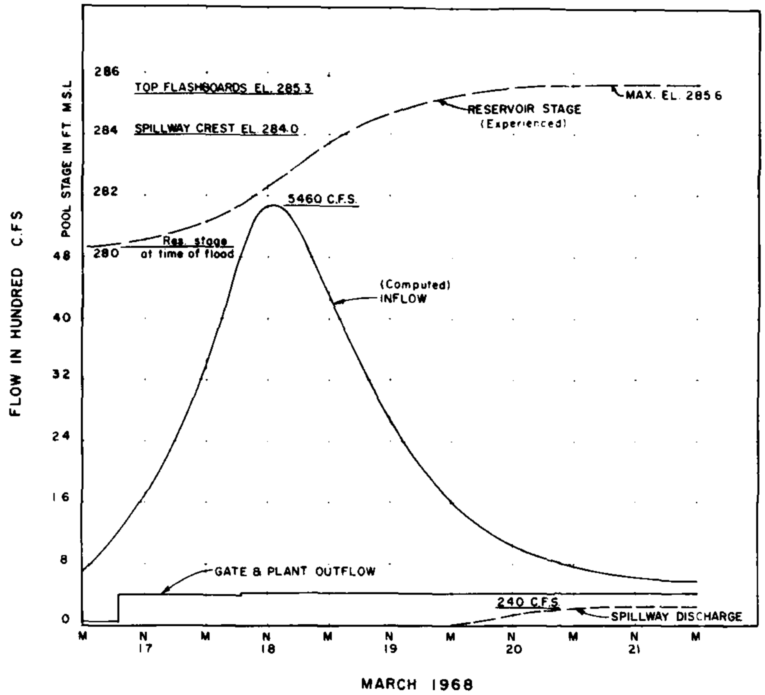

PROVIDENCE
RHODE ISLAND
FREQUENCY OF TIDAL FLOODING
FROM HURRICANES AND STORMS
U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.
LEGEND
⊙ Elevation based on tide gage or high water mark referred to a 26 year period, 1931-1956, inclusive.
□ Elevation based on high water mark referred to a 142 year period, 1815-1956, inclusive.
△ Approximate elevation based on historical account, referred to a 322 year period, 1635-1956, inclusive.
DESIGN HURRICANE TIDE, EL. 20.5
Estimated 1638
Estimated 1635
1938 adjusted from a 26 year period to a 142 year period
1954 adjusted from a 26 year period to a 142 year period
1815
1944
Predicted Maximum Spring High Water
Predicted Mean Spring High Water
Mean High Water
FREQUENCY IN YEARS
2,000
1,000
500
200
100
50
20
10
5
3.33
2.5
2
1.67
1.43
1.25
1.11
1.05
1.02
1.01
PERCENT CHANCE OF OCCURRENCE PER YEAR
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
99.99
ELEVATION EQUALLED OR EXCEEDED IN FEET ABOVE M.S.L.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

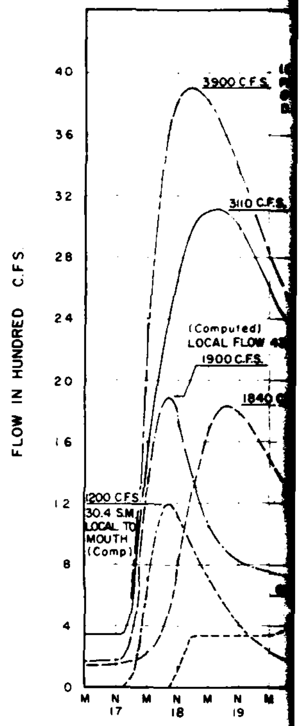
PLATE 4

CORPS OF ENGINEERS

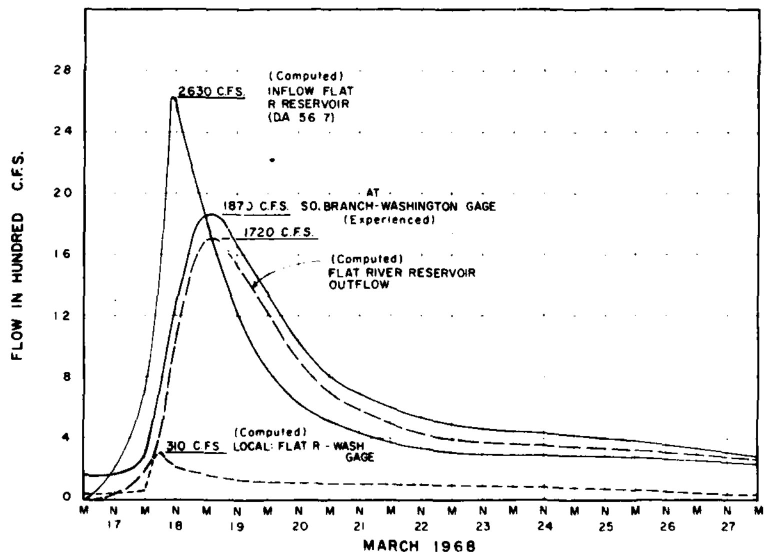


SCITUATE RESERVOIR

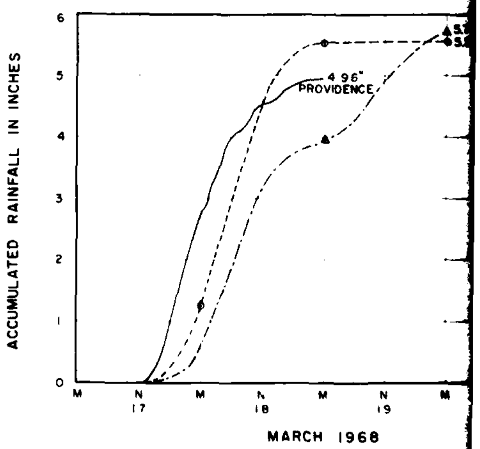
(DA. 92.8 Sq. Mi.)



FLOOD COMPO



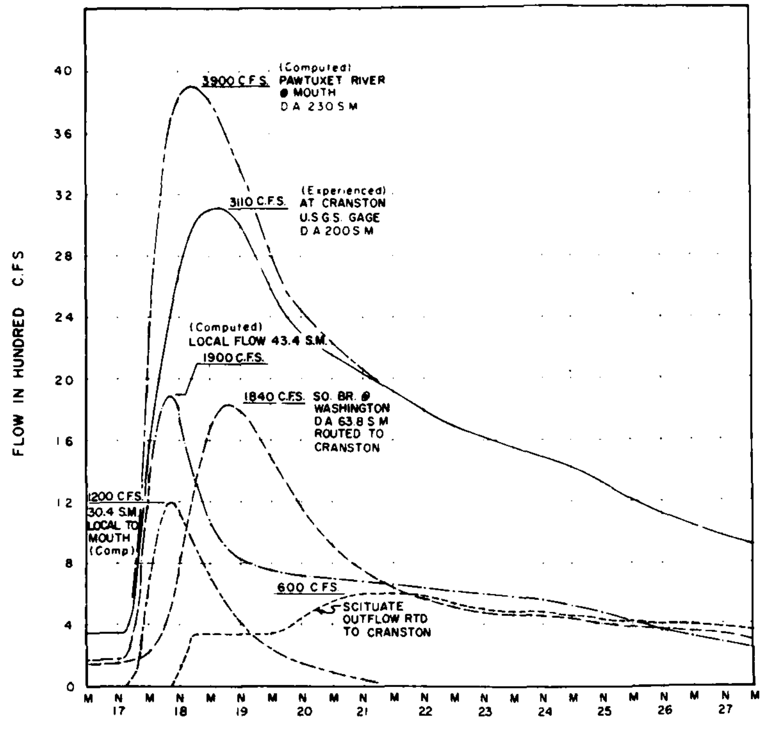
SOUTH BRANCH PAWTUXET RIVER
AT
WASHINGTON R.I. (DA 63.8 Sq Mi)



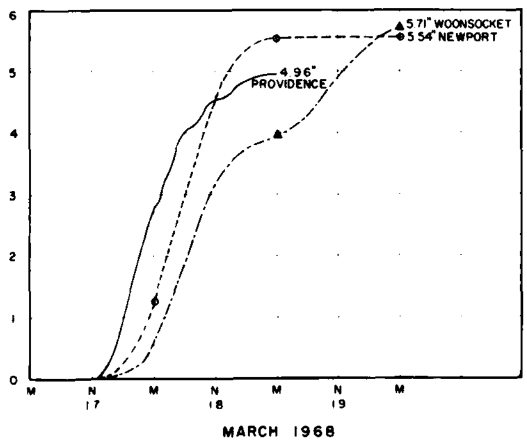
MASS RAINFALL CURVES

(●, △ INDICATE OBSERVED RAINFALL VALU

D E F G H U. S ARMY



FLOOD COMPONENTS AT CRANSTON U.S.G.S. GAGE AND AT MOUTH OF PAWTUXET RIVER



MASS. RAINFALL CURVES

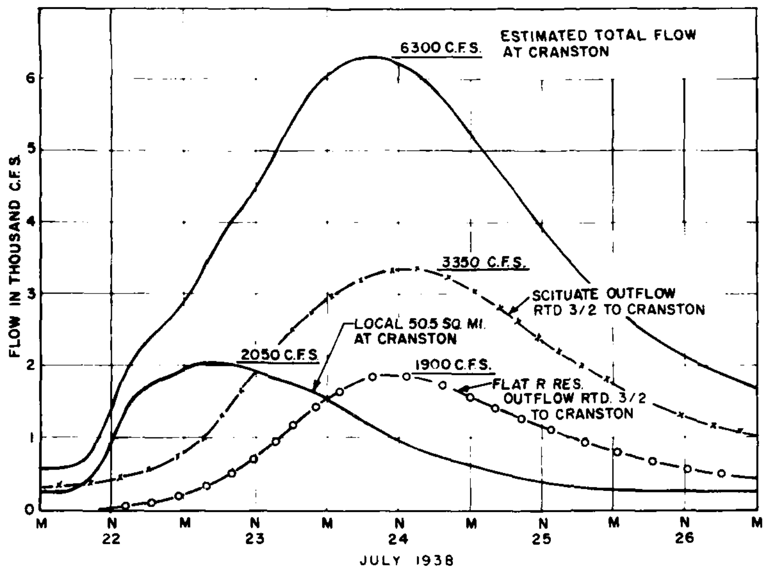
(⊕, △ INDICATE OBSERVED RAINFALL VALUE)

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

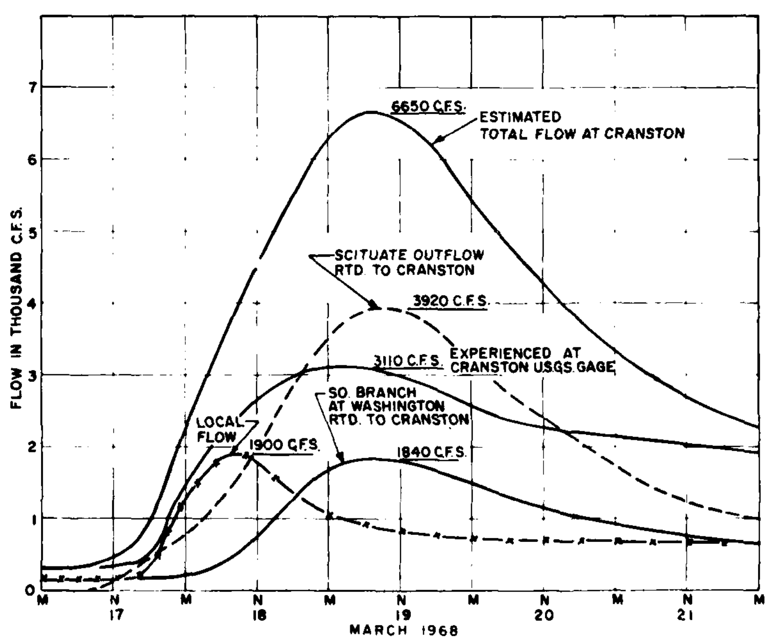
WATER RESOURCES DEVELOPMENT PROJECT

PAWTUXET RIVER BASIN
MARCH 1968 FLOOD
ANALYSIS

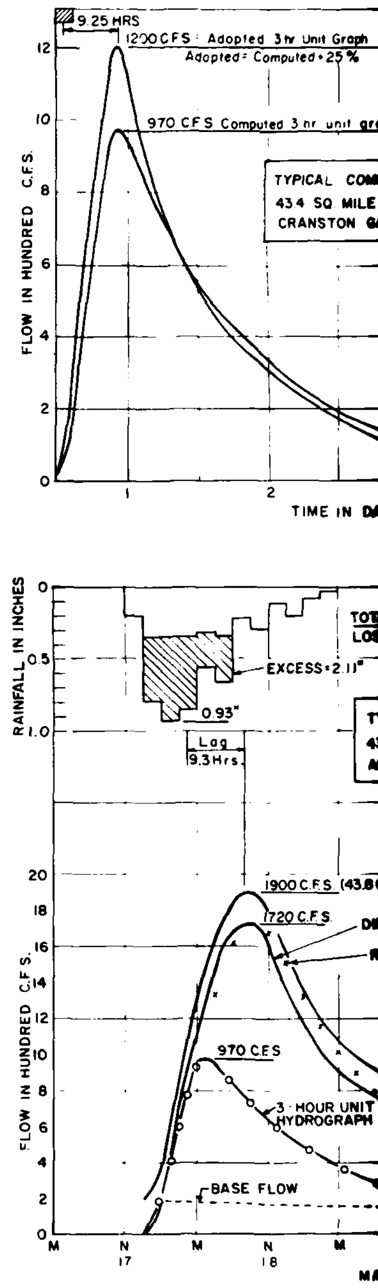
PAWTUXET RIVER RHODE ISLAND



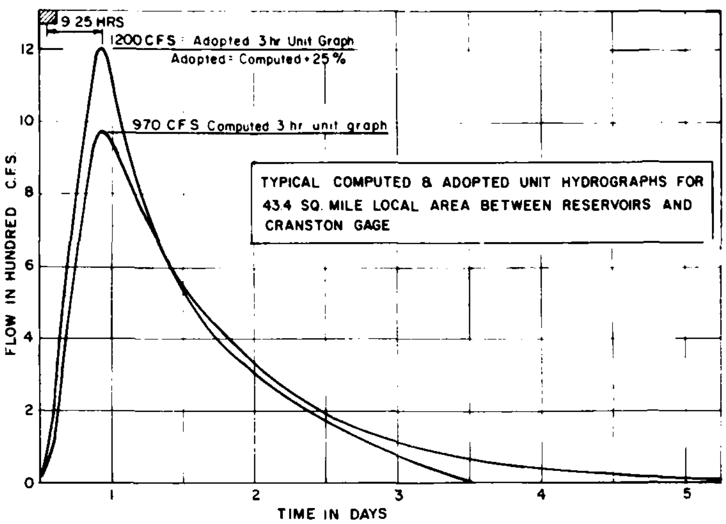
RECONSTRUCTED JULY 1938 FLOOD
AT CRANSTON R.I.

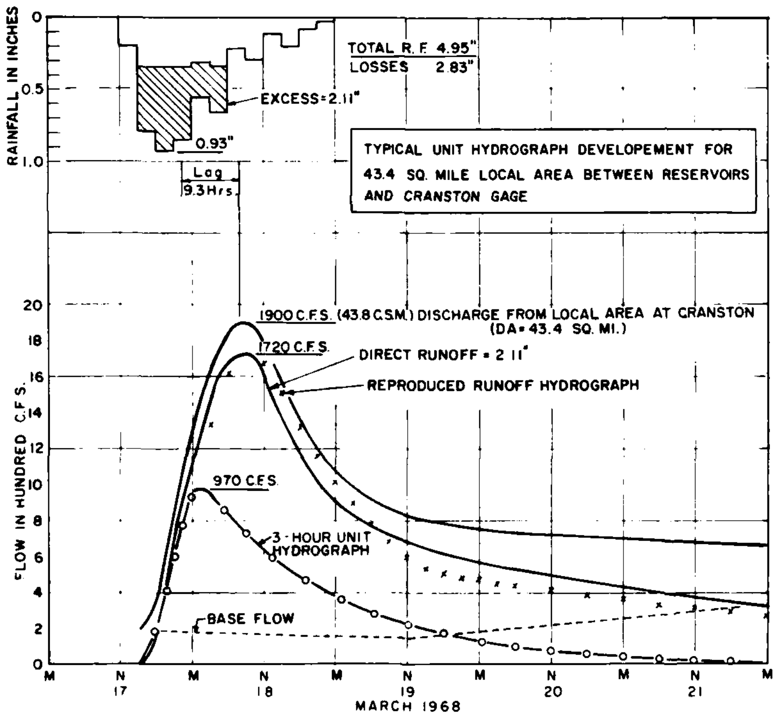


HYPOTHETICAL MARCH 1968 FLOOD
IF SCITUATE RESERVOIR WAS FULL AT START OF FLOOD



UNIT HYDR





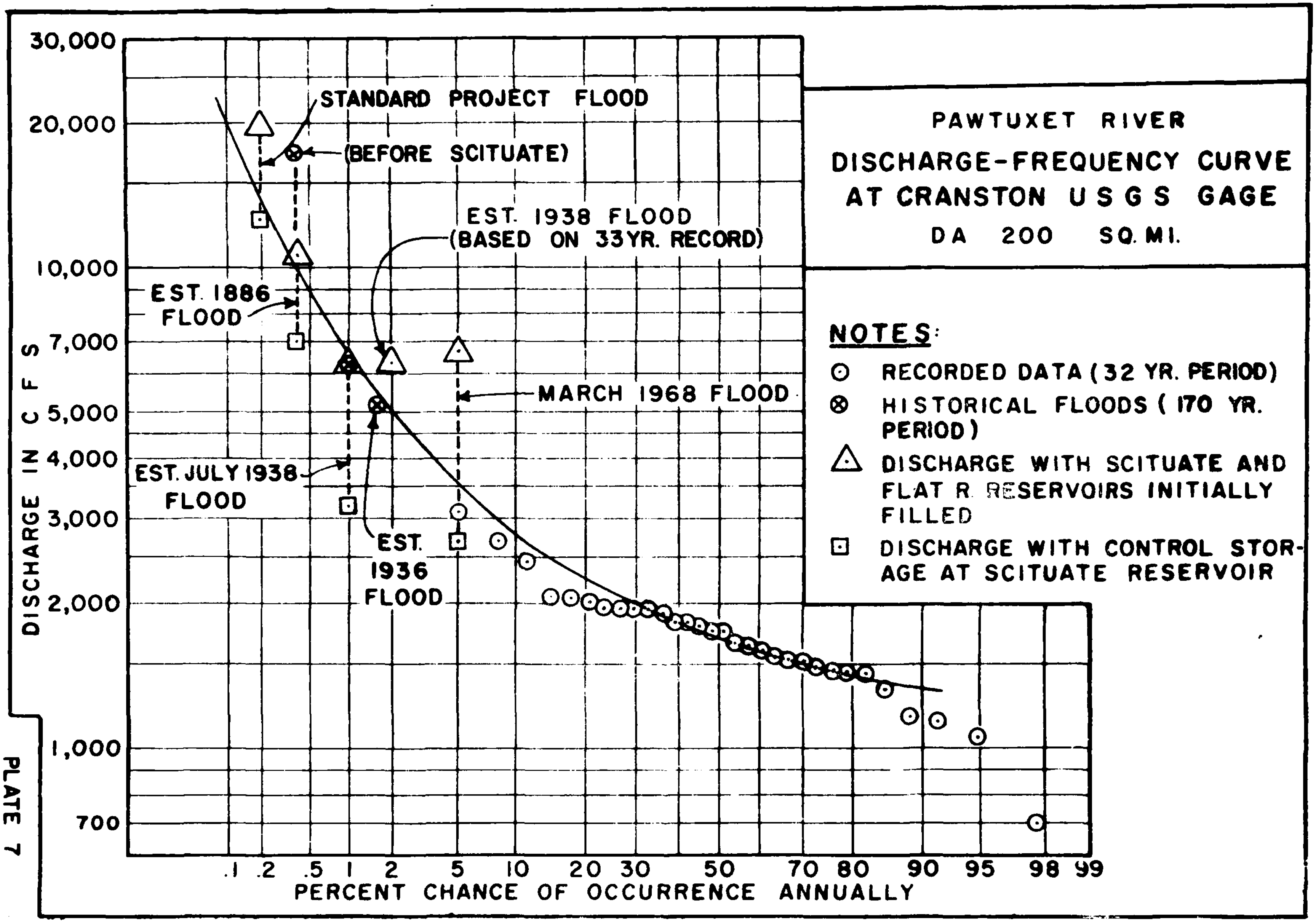
UNIT HYDROGRAPH ANALYSIS

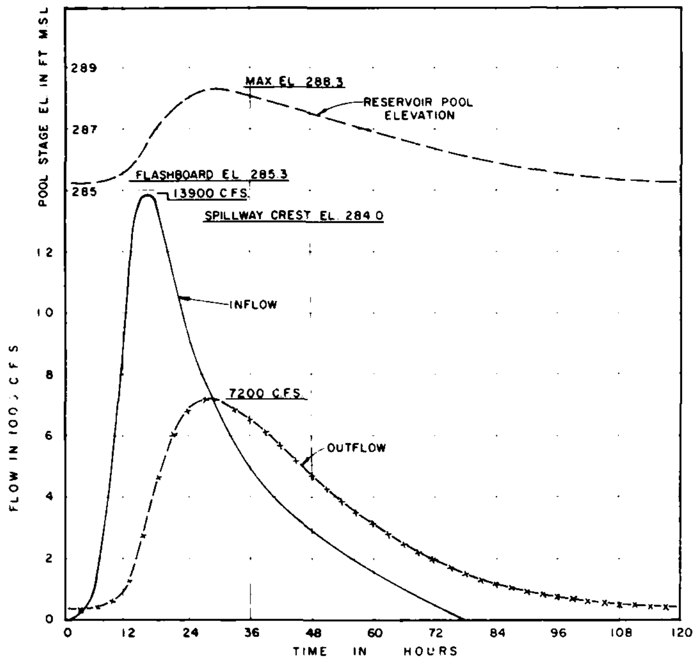
WATER RESOURCES DEVELOPMENT PROJECT

PAWTUXET RIVER BASIN
FLOOD COMPONENTS
AND
UNIT HYDROGRAPH
ANALYSIS

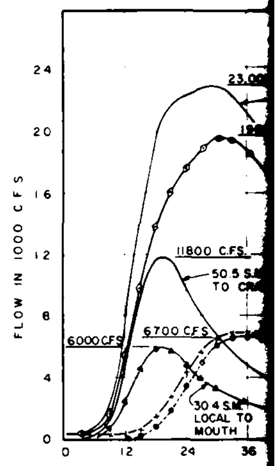
PAWTUXET RIVER | RHODE ISLAND

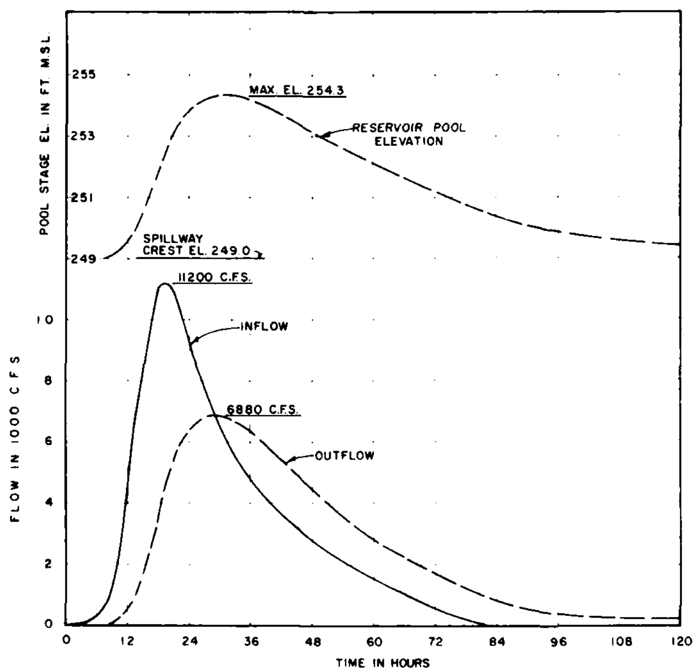
PLATE 6


PAWTUXET RIVER
DISCHARGE-FREQUENCY CURVE
AT CRANSTON U S G S GAGE
DA 200 SQ. MI.
NOTES:
RECORDED DATA (32 YR. PERIOD)
HISTORICAL FLOODS (170 YR. PERIOD)
DISCHARGE WITH SCITUATE AND FLAT R. RESERVOIRS INITIALLY FILLED
DISCHARGE WITH CONTROL STORAGE AT SCITUATE RESERVOIR
STANDARD PROJECT FLOOD
(BEFORE SCITUATE)
EST. 1938 FLOOD
(BASED ON 33 YR. RECORD)
EST. 1886 FLOOD
MARCH 1968 FLOOD
EST. JULY 1938 FLOOD
EST. 1936 FLOOD
DISCHARGE IN C F S
30,000
20,000
10,000
7,000
5,000
4,000
3,000
2,000
1,000
700
.1 .2 .5 1 2 5 10 20 30 50 70 80 90 95 98 99
PERCENT CHANCE OF OCCURRENCE ANNUALLY

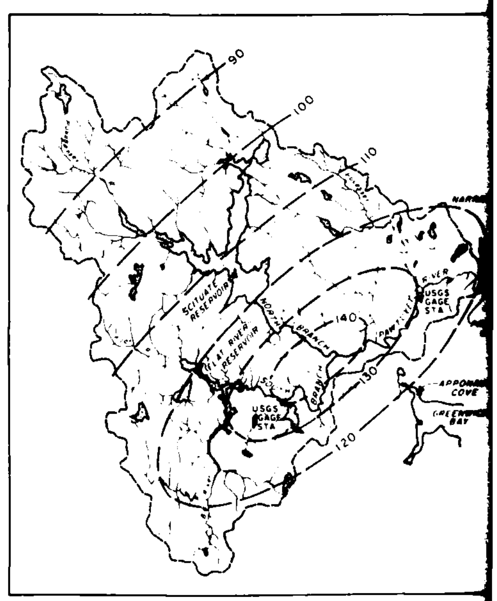


SCITUATE RESERVOIR



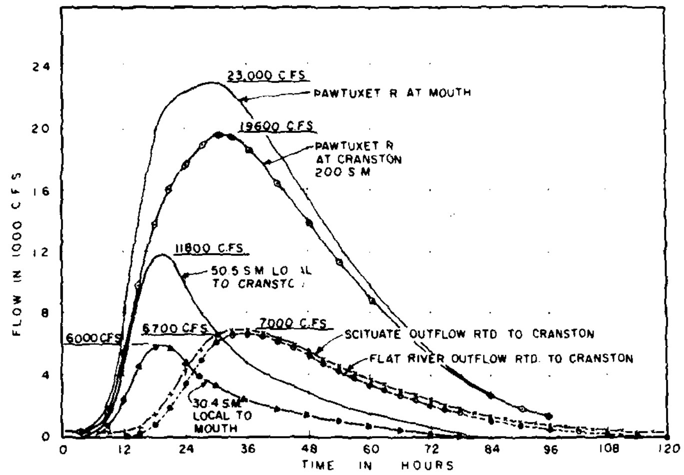


FLAT RIVER RESERVOIR

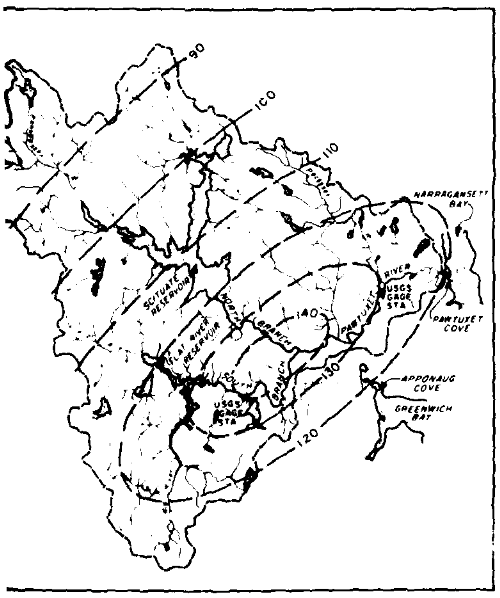


STANDARD PROJECT STORM

PATTERN IN PERCENT OF 96 HR-200 SQ. MILE INDEX RAINFALL



PAWTUXET RIVER BASIN



STANDARD PROJECT STORM
PATTERN IN PERCENT OF 96 HR-200 SQ. MILE INDEX RAINFALL

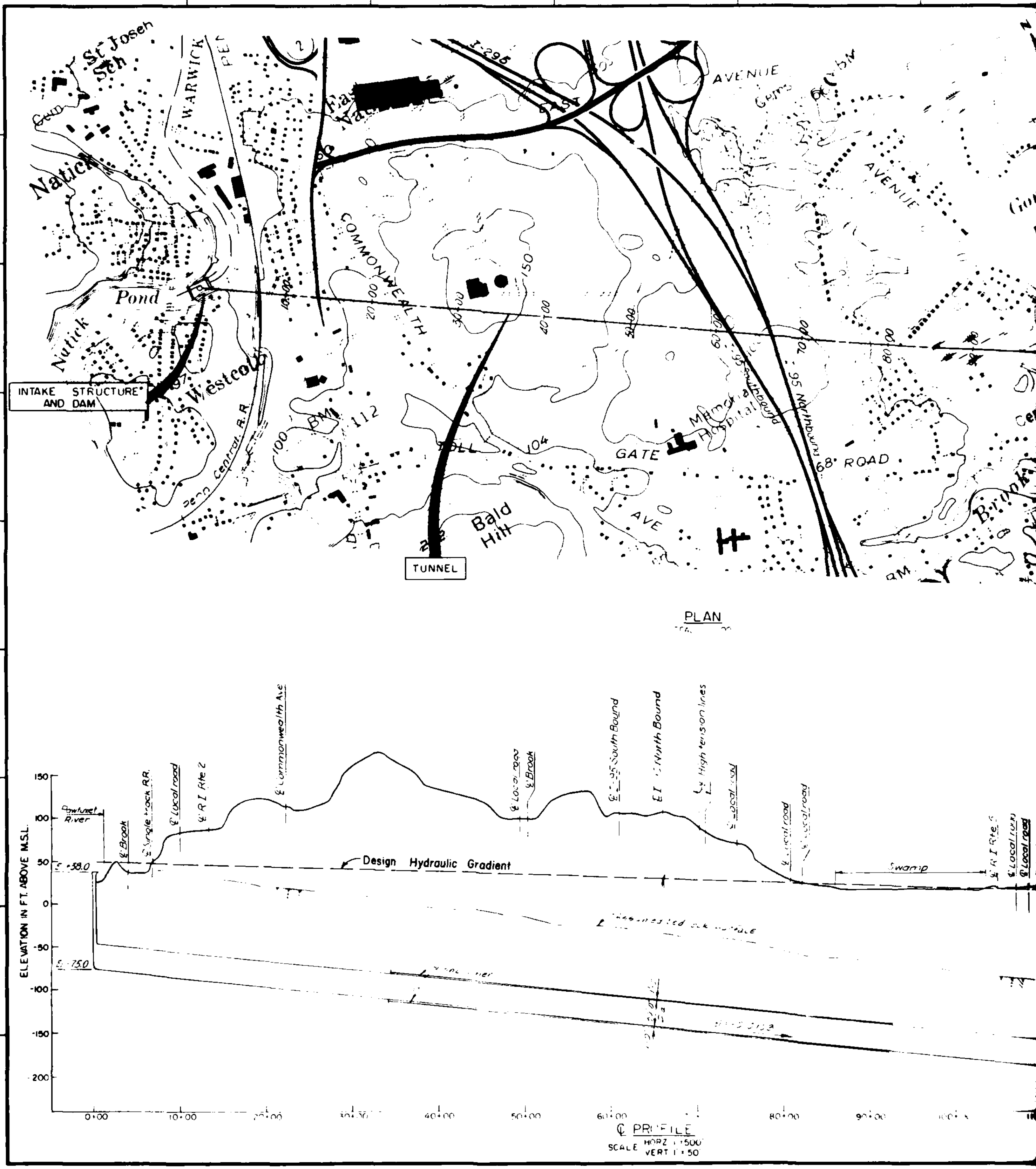
U. S. ARMY

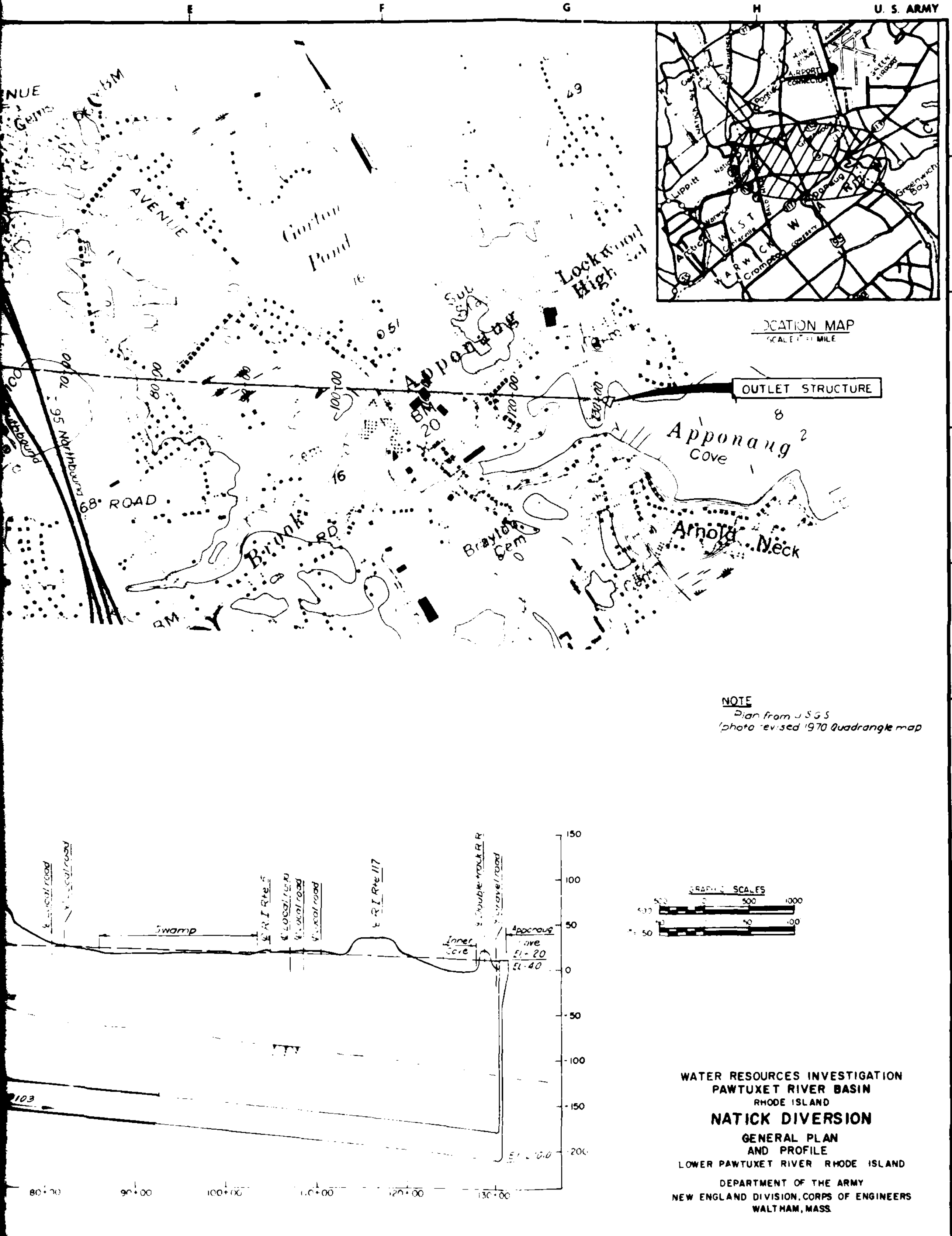
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
STANDARD PROJECT FLOOD
PAWTUXET RIVER — RHODE ISLAND

PLATE 8

CORPS OF ENGINEERS





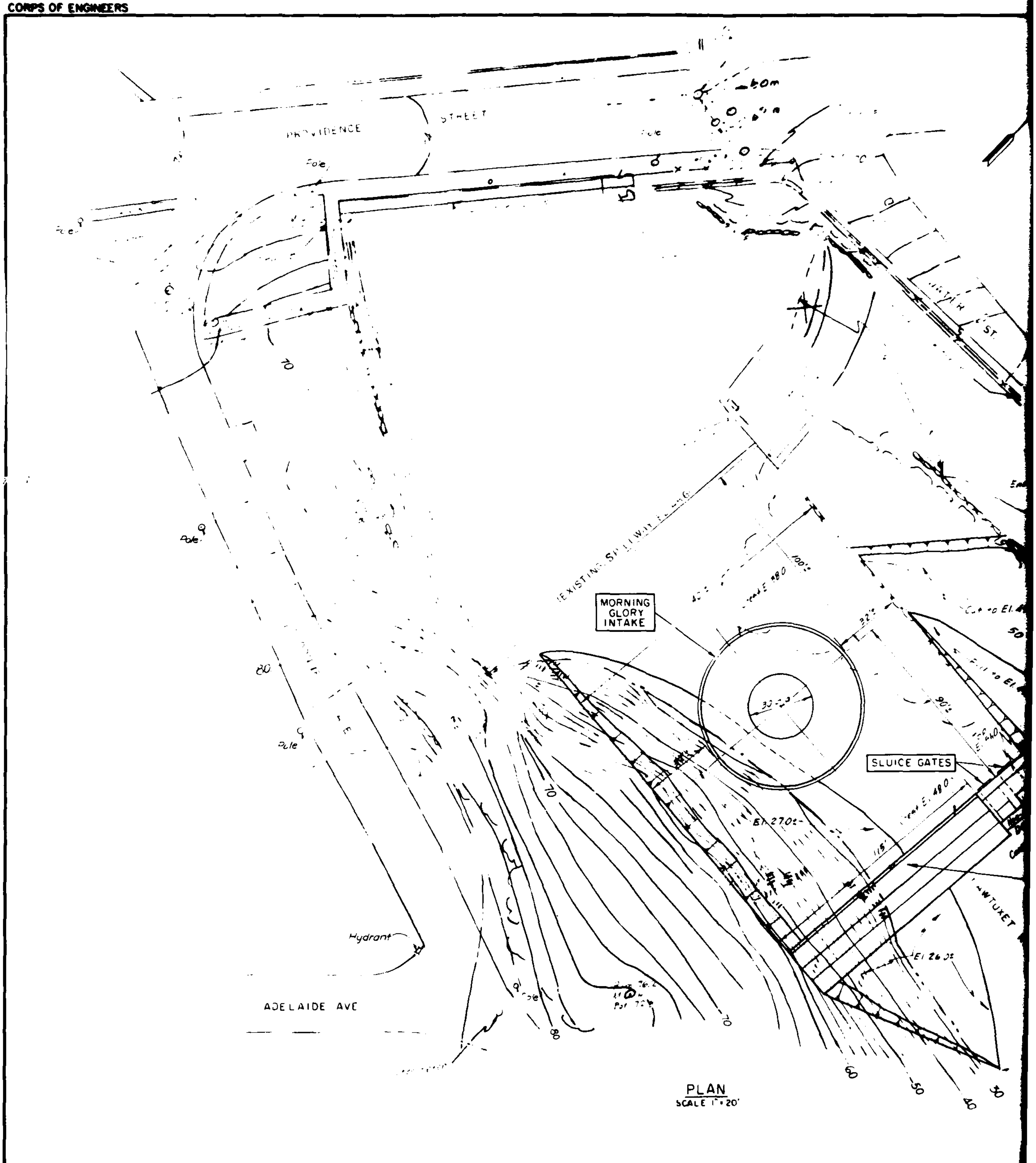
WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND

NATICK DIVERSION

GENERAL PLAN
AND PROFILE
LOWER PAWTUXET RIVER RHODE ISLAND

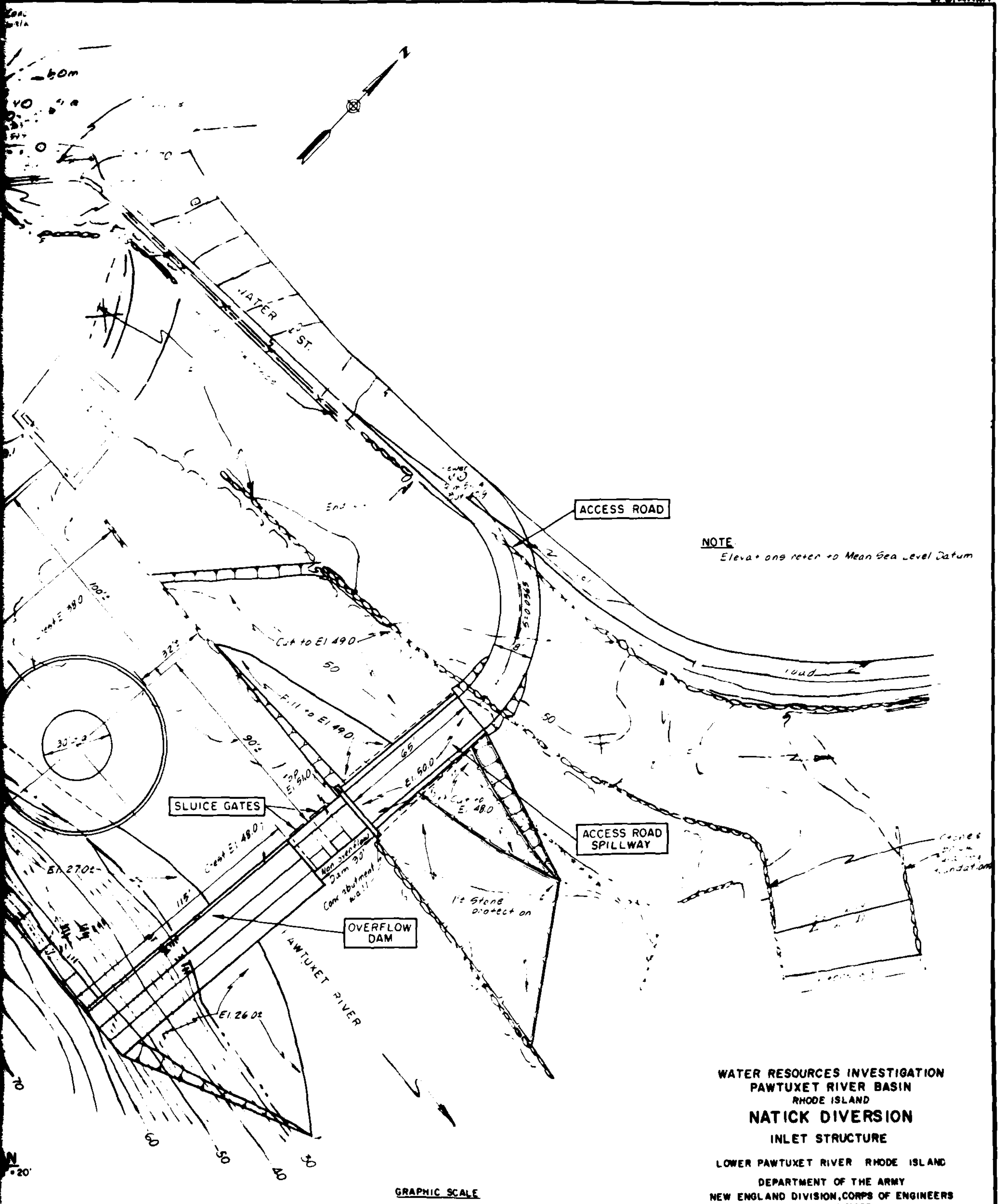
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 9



PLAN
SCALE 1" = 20'

U. S. ARMY



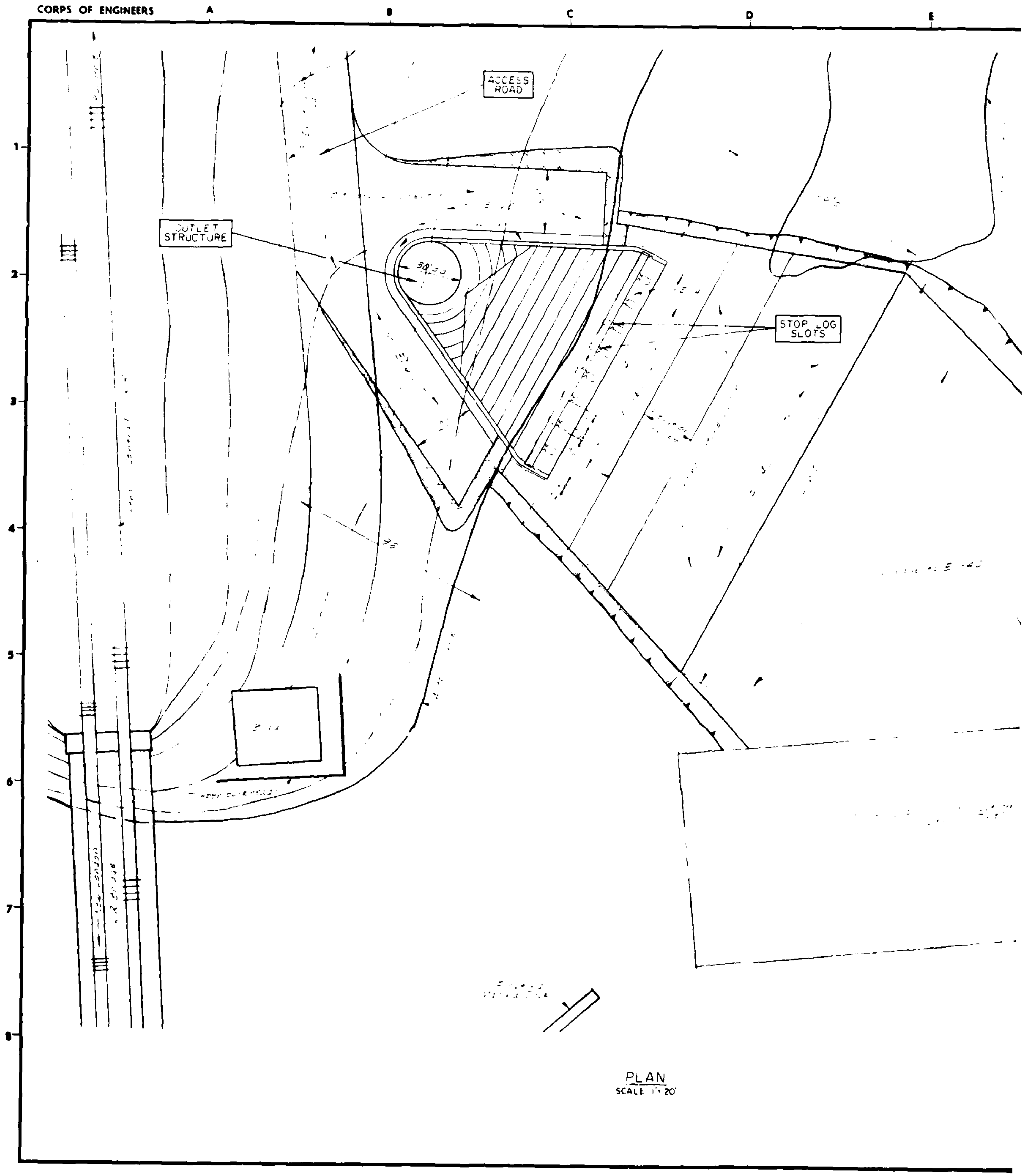
WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND

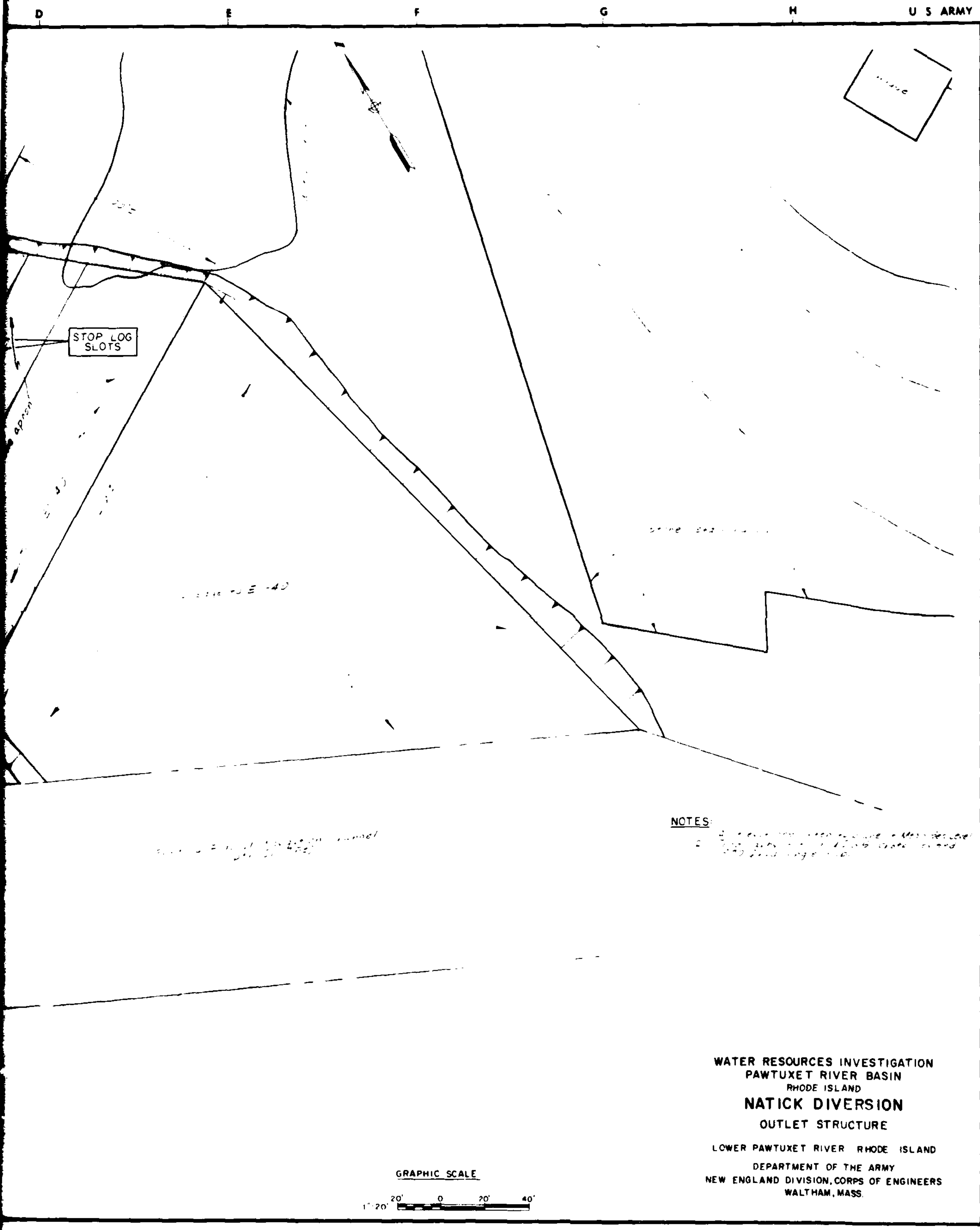
NATICK DIVERSION

INLET STRUCTURE

LOWER PAWTUXET RIVER RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.


CORPS OF ENGINEERS
ACCESS ROAD
OUTLET STRUCTURE
STOP LOG SLOTS
PLAN
SCALE 1" = 20'



WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND

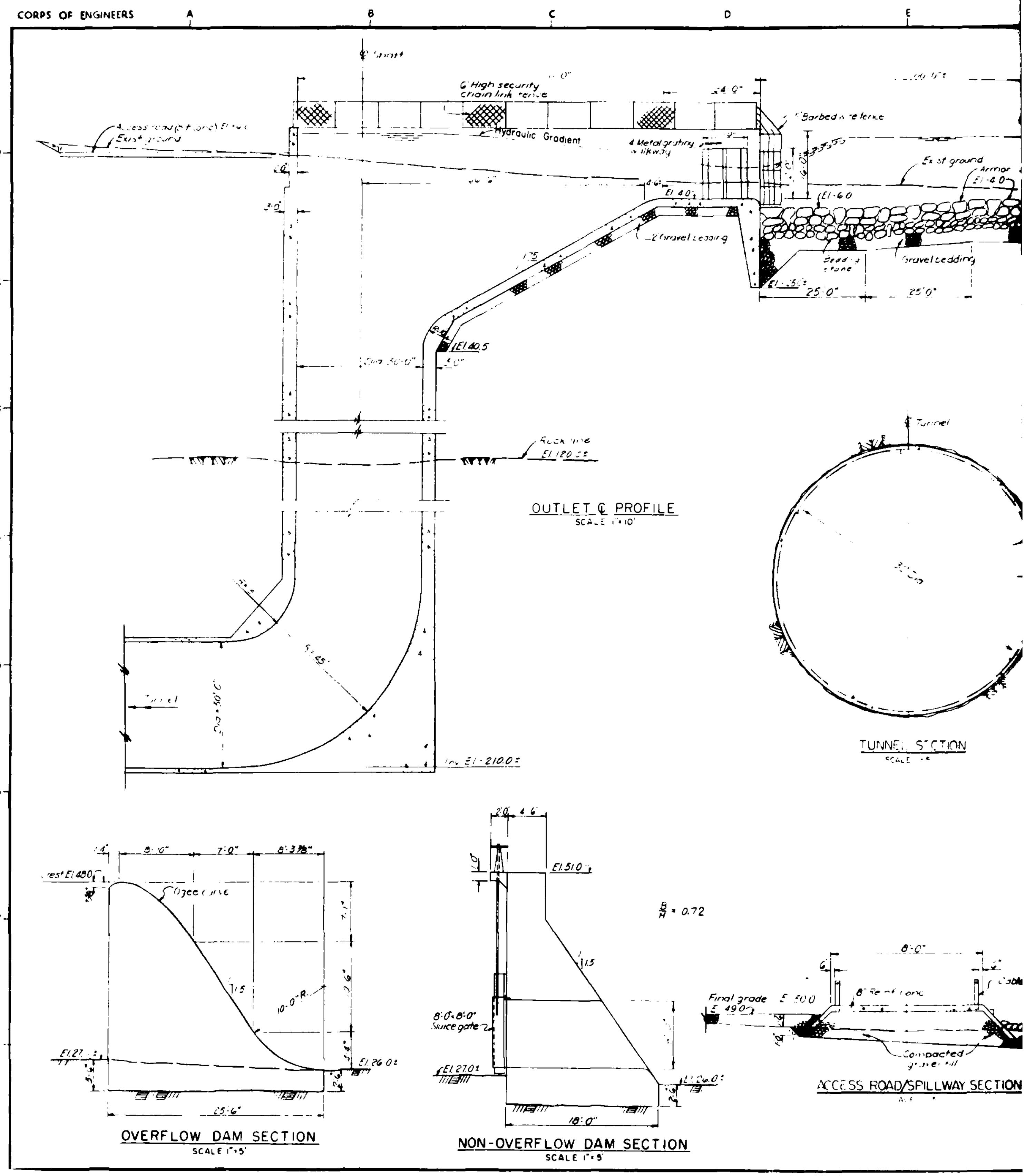
NATICK DIVERSION

OUTLET STRUCTURE

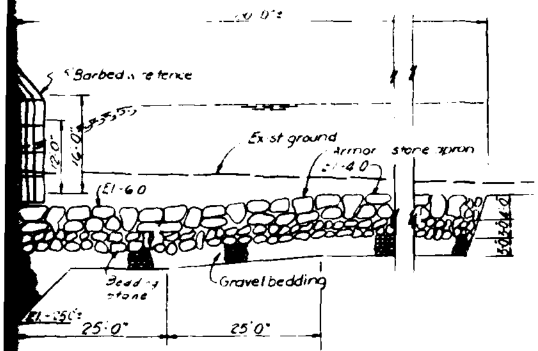
LOWER PAWTUXET RIVER RHODE ISLAND

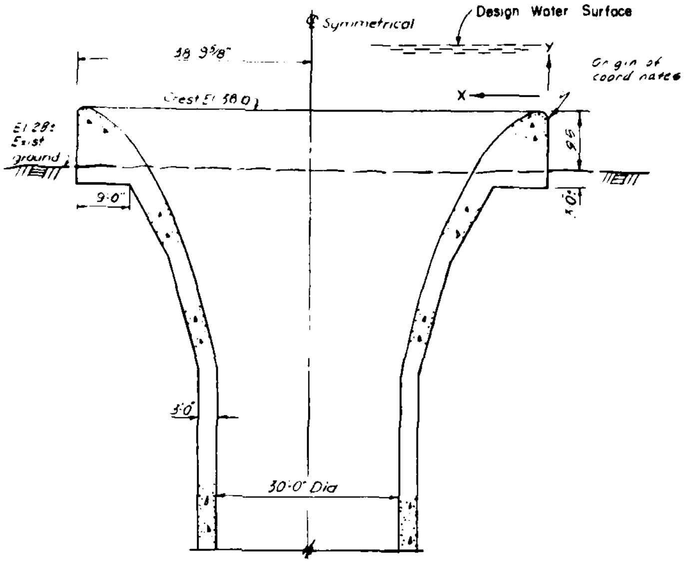
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 11


CORPS OF ENGINEERS
A
B
C
D
E
1
2
3
4
5
6
7
8
6' High security chain link fence
Hydraulic Gradient
4 Metal grating walkway
Barbed wire fence
Exist ground
Armor
Gravel bedding
Bedding stone
25'-0"
El 40.5
Rock line
El 120.0±
OUTLET ℄ PROFILE
SCALE 1"=10'
Tunnel
Inv El 210.0±
TUNNEL SECTION
Crest El 48.0
Ogee curve
1.5
10'-0" R
El 27
El 26.0±
25'-6"
OVERFLOW DAM SECTION
SCALE 1"=5'
El 51.0
8'-0"×8'-0" Sluice gate
El 27.0±
El 26.0±
18'-0"
NON-OVERFLOW DAM SECTION
SCALE 1"=5'
B/H = 0.72
8'-0"
Final grade
Compacted gravel fill
ACCESS ROAD/SPILLWAY SECTION

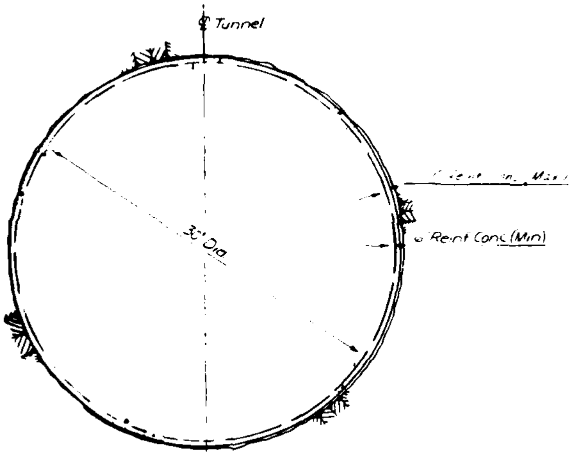
U. S. ARMY





MORNING GLORY SECTION

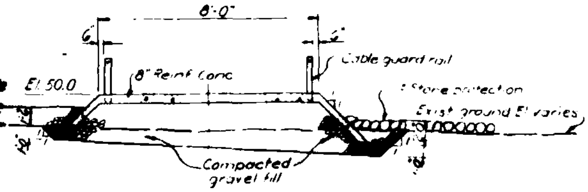
SCALE 1"=10'



TUNNEL SECTION

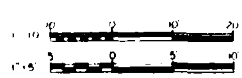
X	Y	FT M.S.L.
0	00	(37.38)
0.7	52	(37.90)
1.4	62	(38.00)
2.1	55	(37.93)
28	35	(37.73)
3.5	06	(37.44)
3.6	0.0	(37.38)
48	-0.7	(36.68)
58	-1.4	(35.98)
67	-2.1	(35.28)
74	-2.8	(34.58)
8.1	-3.5	(33.88)
10.8	-7.0	(30.38)
14.9	-14.0	(23.38)
17.9	-21.0	(16.38)
20.4	-28.0	(9.38)
22.2	-35.0	(2.38)
23.8	-42.0	(-4.62)

MORNING GLORY COORDINATE TABLE



ACCESS ROAD/SPILLWAY SECTION

GRAPHIC SCALES



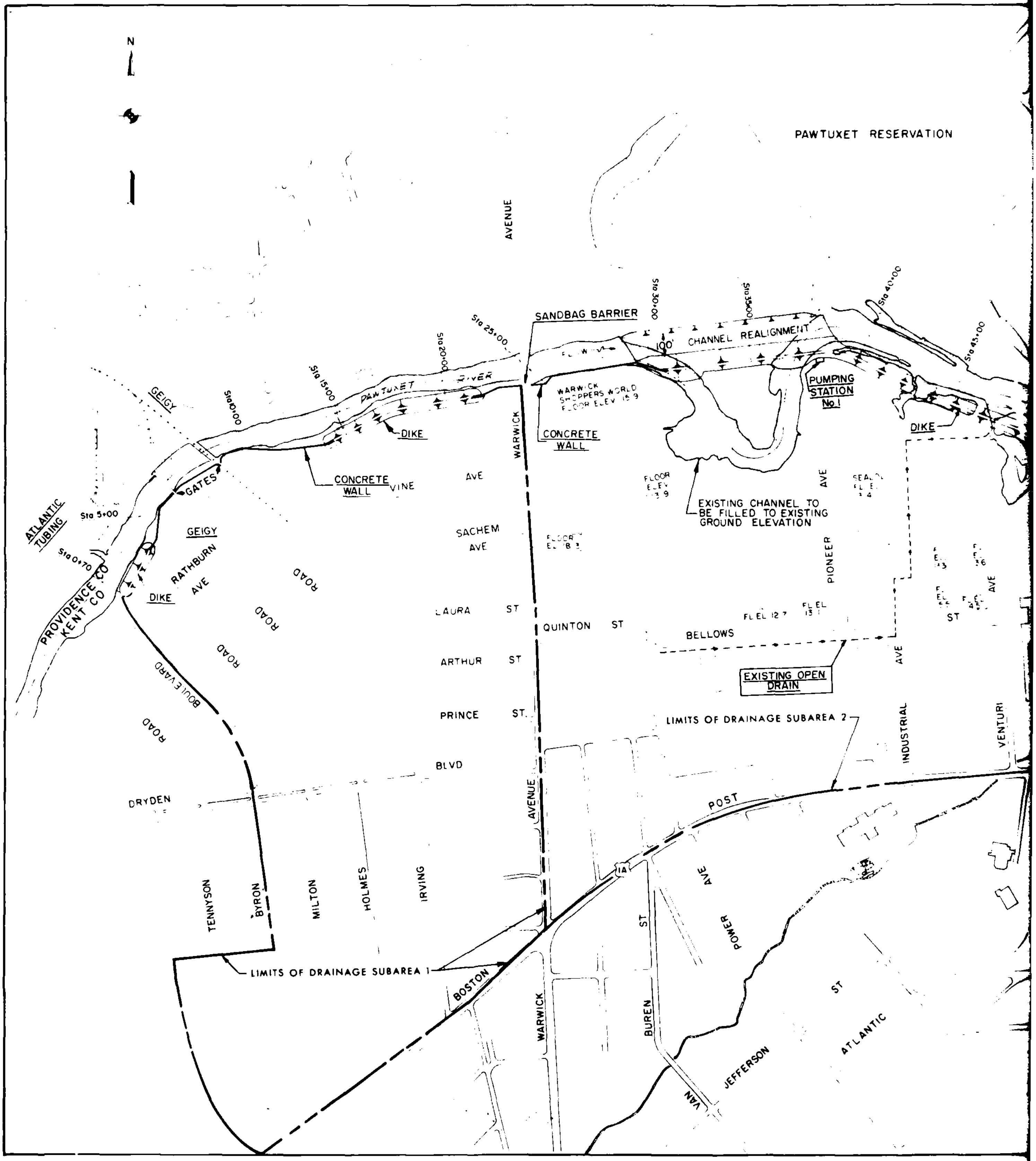
WATER RESOURCES INVESTIGATION
PAWTUXET RIVER BASIN
RHODE ISLAND

NATICK DIVERSION

PROFILE AND SECTIONS

LOWER PAWTUXET RIVER RHODE ISLAND

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS


N
PAWTUXET RESERVATION
AVENUE
SANDBAG BARRIER
Sta 25+00
Sta 20+00
Sta 15+00
Sta 10+00
Sta 30+00
Sta 35+00
Sta 40+00
Sta 45+00
100'
CHANNEL REALIGNMENT
PAWTUXET RIVER
WARWICK SHOPPERS WORLD FLOOR ELEV 15.9
PUMPING STATION No.1
DIKE
CONCRETE WALL
GEIGY
DIKE
WARWICK
CONCRETE WALL
VINE
AVE
EXISTING CHANNEL TO BE FILLED TO EXISTING GROUND ELEVATION
AVE
GATES
ATLANTIC TUBING
Sta 5+00
Sta 0+70
GEIGY
SACHEM AVE
PIONEER
RATHBURN AVE
ROAD
ROAD
DIKE
PROVIDENCE CO
KENT CO
LAURA ST
QUINTON ST
BELLOWS
ST
AVE
ROAD
BOULEVARD
ARTHUR ST
EXISTING OPEN DRAIN
PRINCE ST.
LIMITS OF DRAINAGE SUBAREA 2
ROAD
INDUSTRIAL
VENTURI
BLVD
DRYDEN
AVENUE
POST
1A
TENNYSON
BYRON
MILTON
HOLMES
IRVING
AVE
ST
POWER
LIMITS OF DRAINAGE SUBAREA 1
BOSTON
WARWICK
BUREN
ST
ATLANTIC
JEFFERSON
VAN

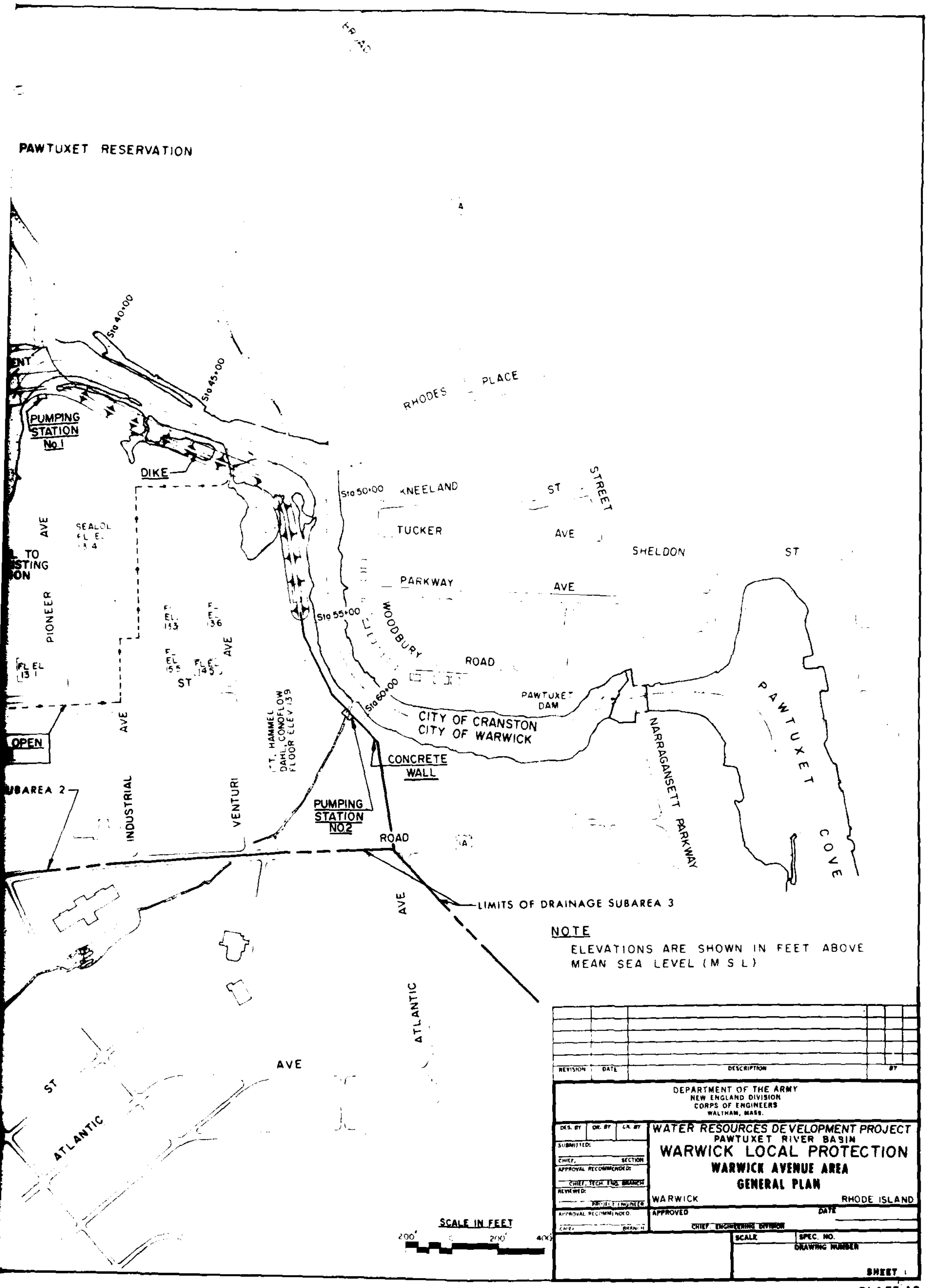
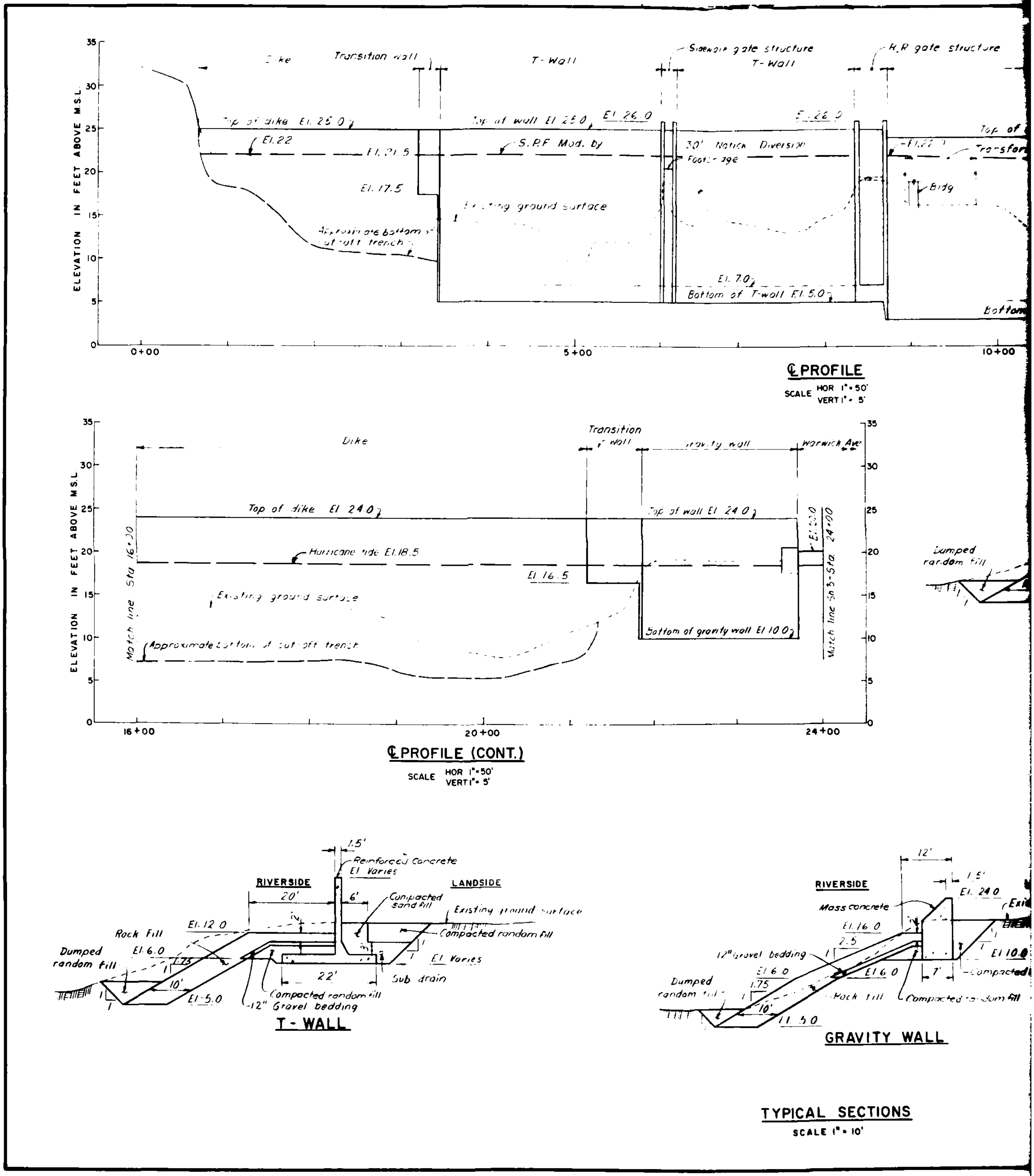
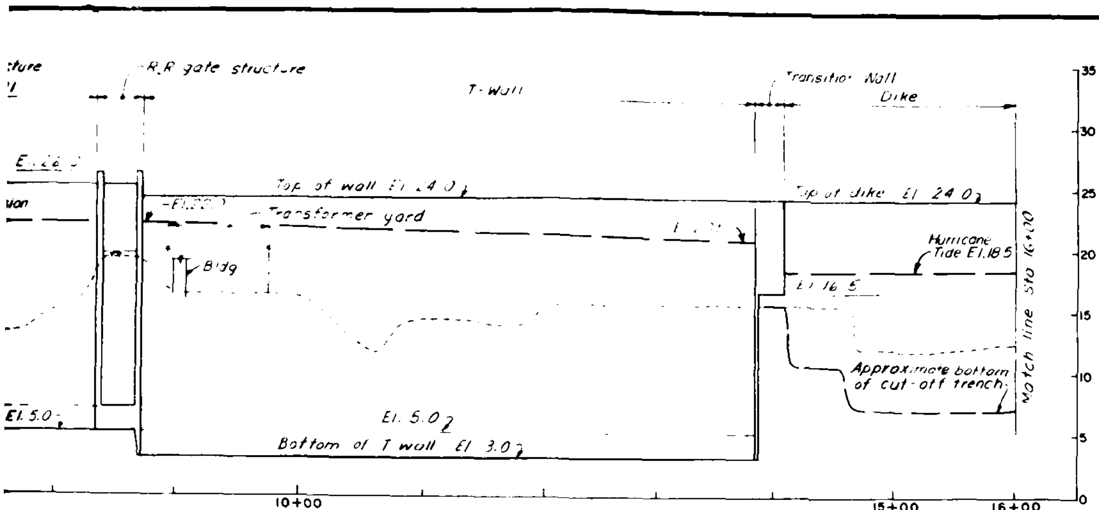

PAWTUXET RESERVATION
Sta 40+00
Sta 45+00
RHODES PLACE
PUMPING STATION No 1
DIKE
Sta 50+00
KNEELAND ST
STREET
TUCKER AVE
SHELDON ST
PARKWAY AVE
SEALOL FL EL 13.4
PIONEER
AVE
Sta 55+00
WOODBURY ROAD
FL EL 13.1
ST
Sta 60+00
PAWTUXET DAM
CITY OF CRANSTON
CITY OF WARWICK
T. HAMMEL DAHL, CONOFLOW FLOOR ELEV 13.9
OPEN
CONCRETE WALL
NARRAGANSETT PARKWAY
PAWTUXET COVE
SUBAREA 2
INDUSTRIAL
VENTURI
PUMPING STATION NO 2
ROAD
LIMITS OF DRAINAGE SUBAREA 3
NOTE
ELEVATIONS ARE SHOWN IN FEET ABOVE MEAN SEA LEVEL (M S L)
ATLANTIC
AVE
ST
ATLANTIC
SCALE IN FEET
200 0 200 400
REVISION DATE DESCRIPTION BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
GENERAL PLAN
WARWICK
RHODE ISLAND
APPROVED
DATE
CHIEF, ENGINEERING DIVISION
SCALE
SPEC. NO.
DRAWING NUMBER
SHEET 1

PLATE 13

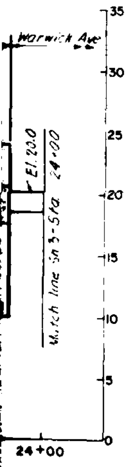


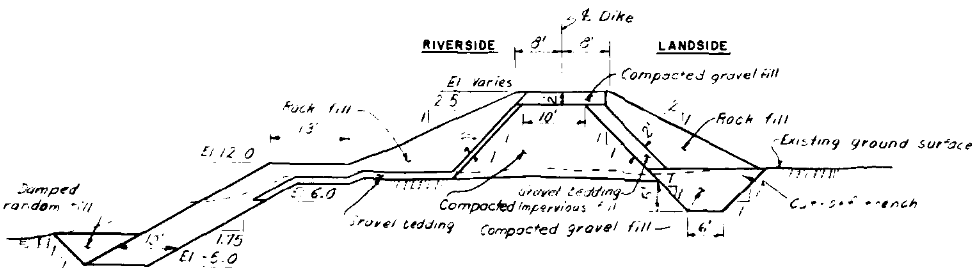
Dike
Transition wall
T-Wall
Sidewalk gate structure
T-Wall
R.R gate structure
Top of dike El. 25.0
Top of wall El 25.0
El 26.0
El 26.0
El 22
El 21.5
S.P.F. Mod. by
30' Natick Diversion
Footage
El. 17.5
Existing ground surface
Approximate bottom of cut-off trench
Bldg
El. 7.0
Bottom of T-wall El. 5.0
ELEVATION IN FEET ABOVE M.S.L.
0+00
5+00
10+00
℄ PROFILE
SCALE HOR 1" = 50' VERT 1" = 5'
Dike
Transition wall
Gravity wall
Warwick Ave
Top of dike El 24.0
Top of wall El 24.0
Hurricane tide El. 18.5
El 16.5
Existing ground surface
Approximate bottom of cut-off trench
Bottom of gravity wall El 10.0
Match line Sta 16+00
Match line Sta 3-5 Sta 24+00
16+00
20+00
24+00
℄ PROFILE (CONT.)
SCALE HOR 1" = 50' VERT 1" = 5'
1.5'
Reinforced Concrete
El Varies
RIVERSIDE
LANDSIDE
20'
6'
Compacted sand fill
Existing ground surface
Compacted random fill
Rock Fill
El. 12.0
Dumped random fill
El. 6.0
1.75
10'
El. 5.0
22'
El Varies
Sub drain
Compacted random fill
12" Gravel bedding
T-WALL
12'
1.5'
El. 24.0
RIVERSIDE
Mass concrete
El. 16.0
2.5
12" Gravel bedding
El 6.0
El 6.0
El 10.0
7'
Compacted
1.75
Dumped random fill
10'
Rock fill
Compacted random fill
El. 5.0
GRAVITY WALL
TYPICAL SECTIONS
SCALE 1" = 10'



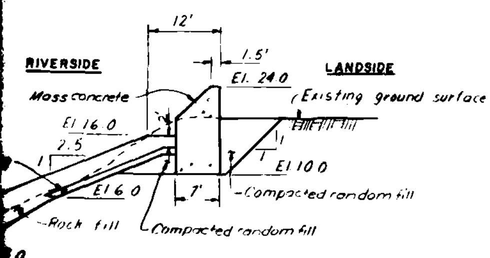
PROFILE

SCALE HOR 1" = 50' VERT 1" = 5'

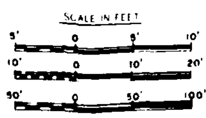




DIKE



GRAVITY WALL



TYPICAL SECTIONS

SCALE 1" = 10'

REVISION	DATE	DESCRIPTION	BY

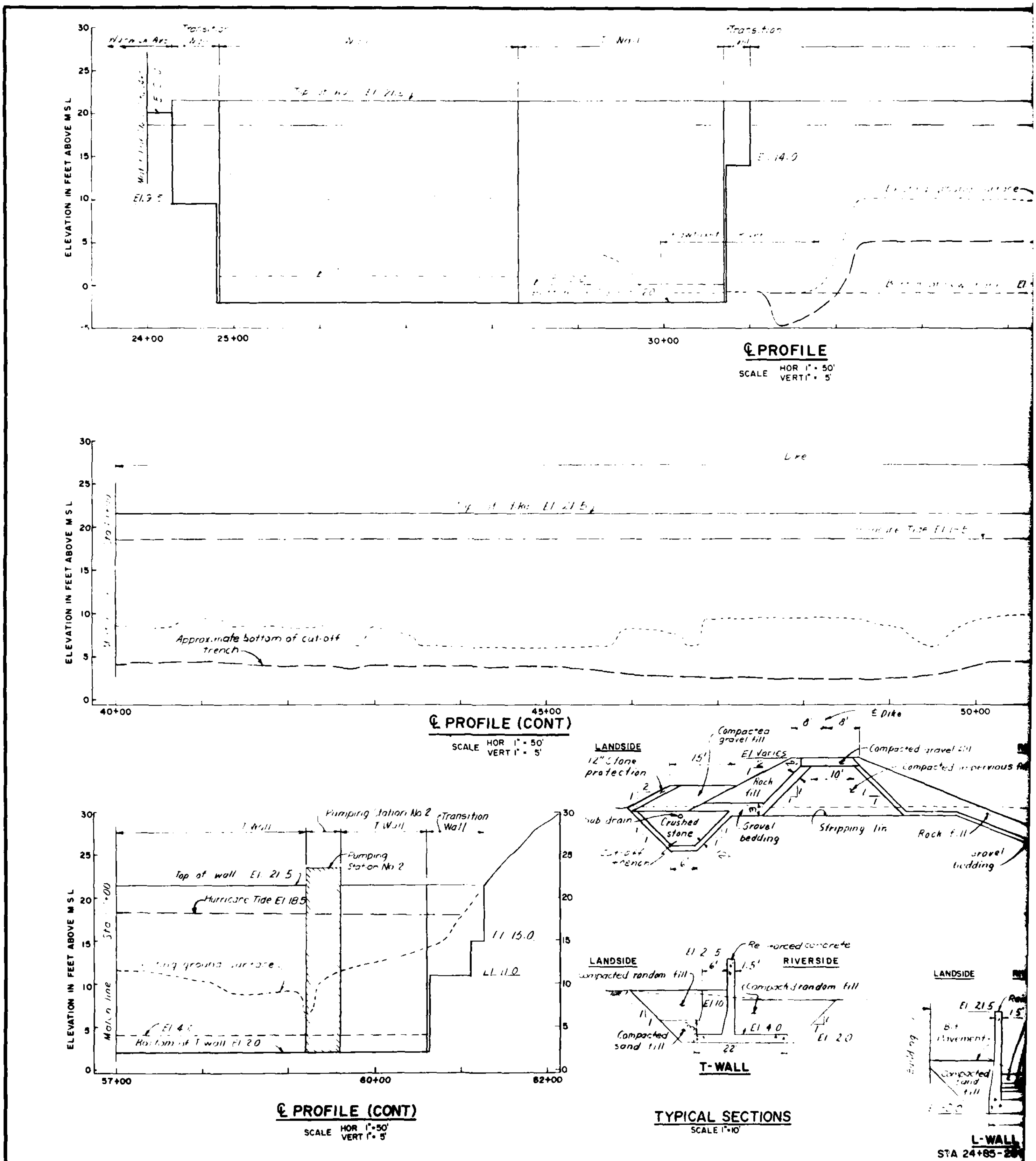
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
PROFILE AND TYPICAL SECTIONS NO. 1
WARWICK RHODE ISLAND

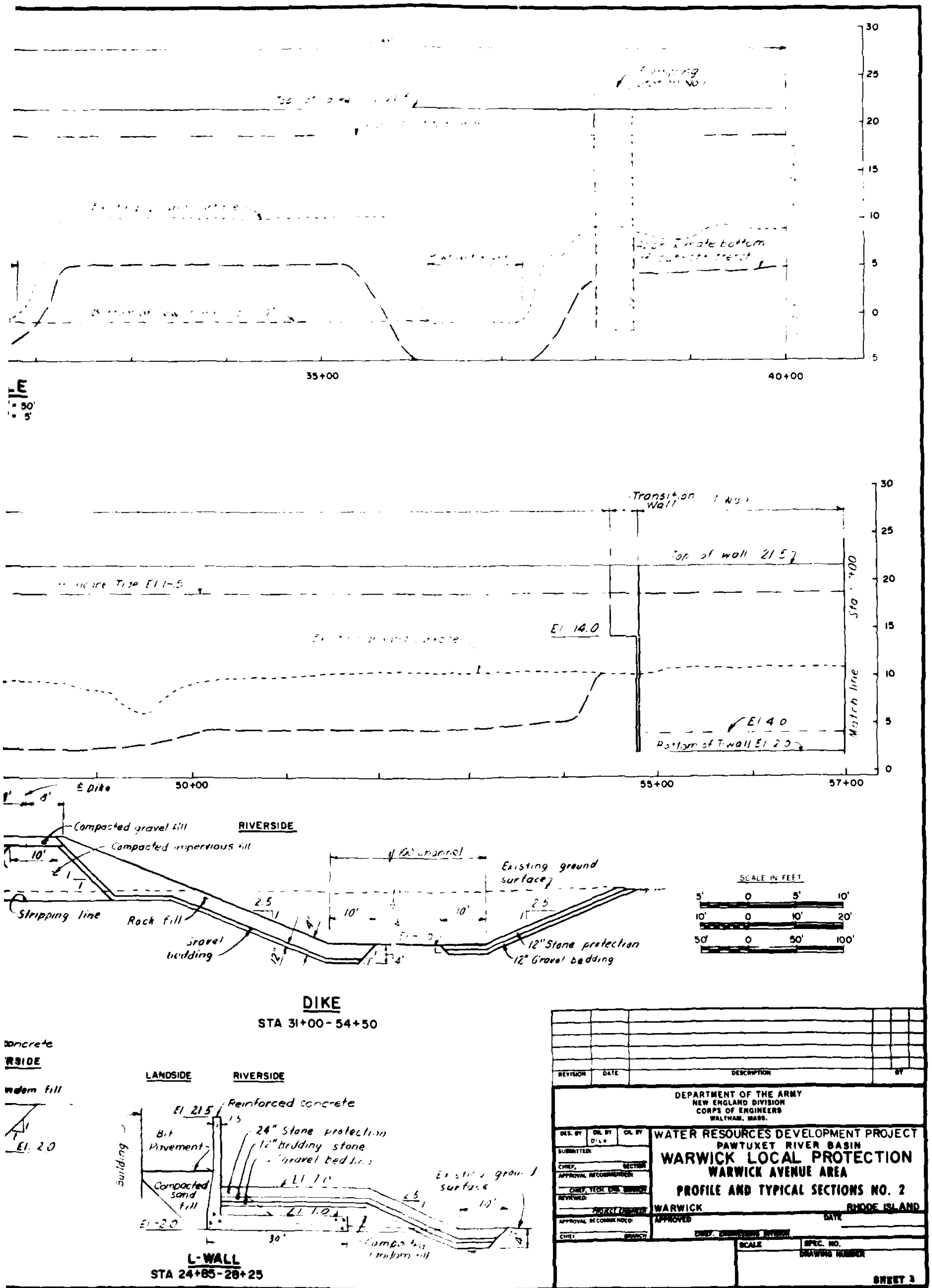
DES. BY | DR. BY | CK. BY | SUBMITTED | CHIEF, SECTION | APPROVAL RECOMMENDED | CHIEF, ENGINEERING DIVISION | APPROVED | DATE | SCALE | SPEC. NO. | DRAWING NUMBER

SHEET 2

PLATE 14



ELEVATION IN FEET ABOVE M S L
Transition
Transition
El. 9.5
El. 14.0
24+00
25+00
30+00
℄ PROFILE
SCALE HOR 1" = 50' VERT 1" = 5'
Approximate bottom of cut-off trench
40+00
45+00
50+00
℄ Dike
℄ PROFILE (CONT)
SCALE HOR 1" = 50' VERT 1" = 5'
T Wall
Pumping Station No 2 T Wall
Transition Wall
Pumping Station No 2
Top of wall El 21.5
Hurricane Tide El 18.5
El 15.0
El 11.0
El 4.0
Bottom of T wall El 2.0
Match line
57+00
60+00
62+00
℄ PROFILE (CONT)
SCALE HOR 1"=50' VERT 1"=5'
LANDSIDE
12" Stone protection
Compacted gravel fill
El Varies
Rock fill
Crushed stone
Gravel bedding
Stripping line
Compacted gravel fill
compacted impervious fill
Rock fill
gravel bedding
Sub drain
Reinforced concrete
LANDSIDE
RIVERSIDE
compacted random fill
Compacted random fill
El 10
El 4.0
El 2.0
Compacted sand fill
22'
T-WALL
TYPICAL SECTIONS
SCALE 1"=10'
LANDSIDE
El 21.5
Bit Pavement
Compacted sand fill
L-WALL
STA 24+85-2

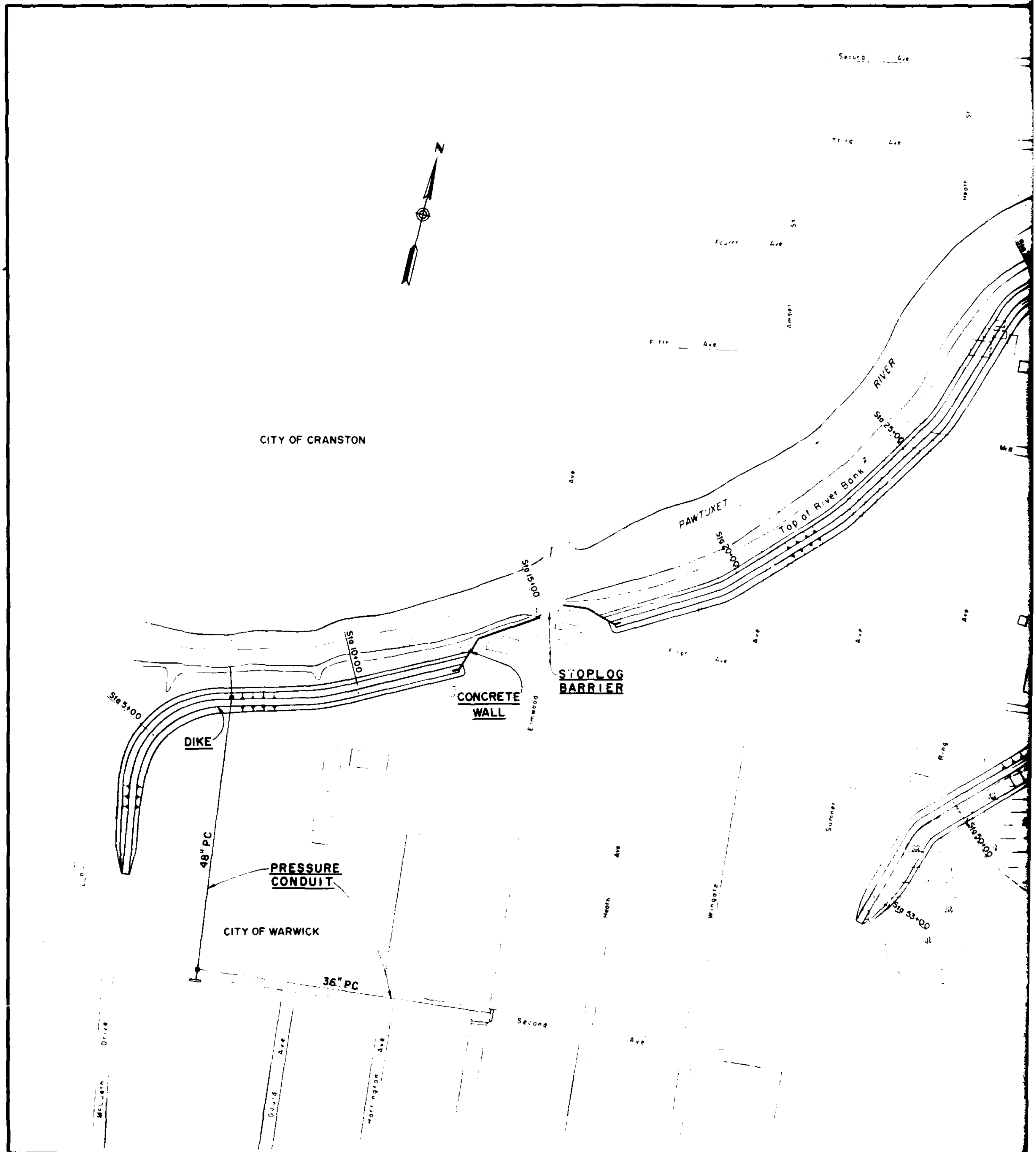


DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

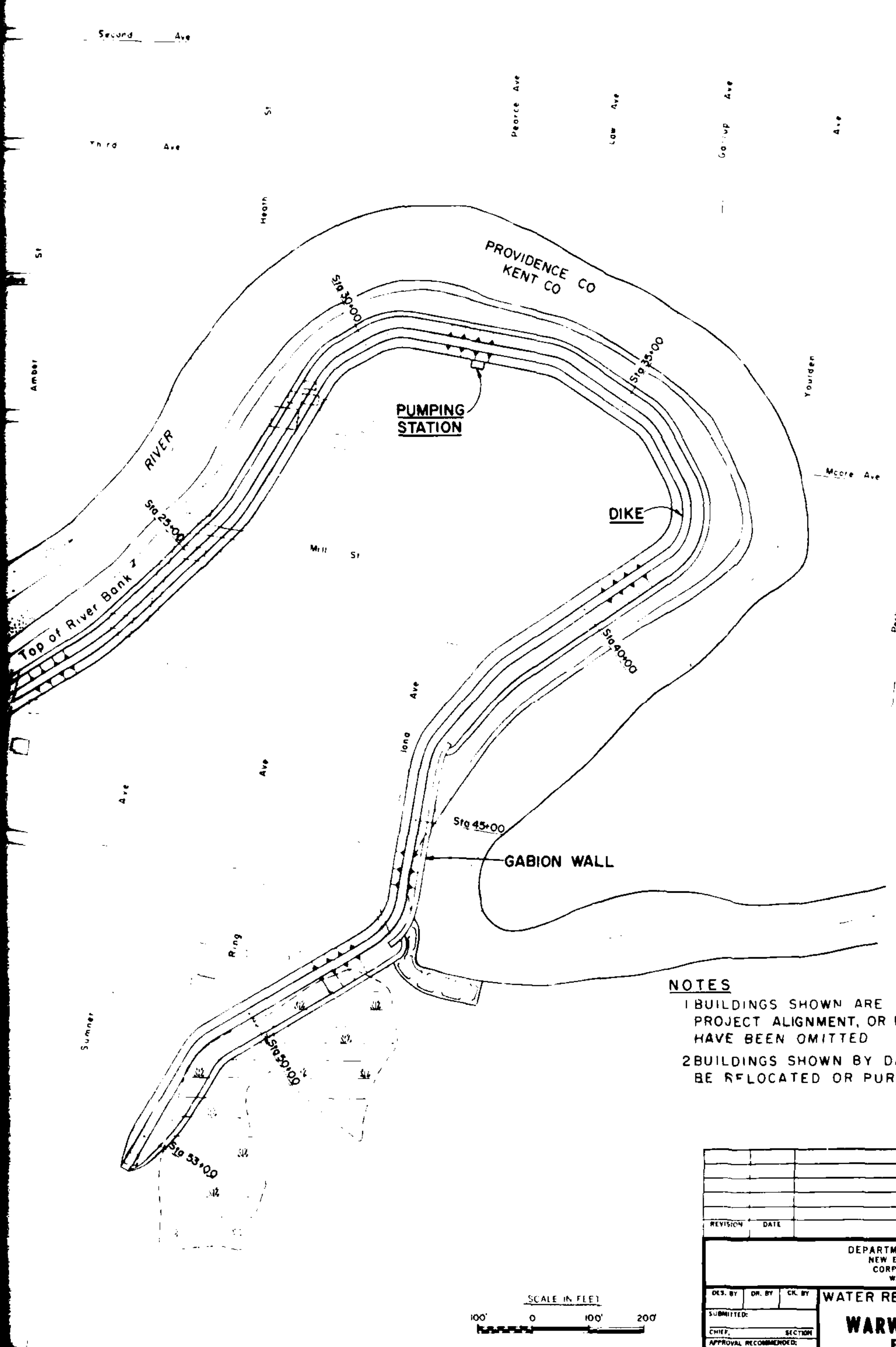
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
PROFILE AND TYPICAL SECTIONS NO. 2
WARWICK RHODE ISLAND

SHEET 3

PLATE 15



N
CITY OF CRANSTON
PAWTUXET
RIVER
Top of River Bank
Sta 5+00
Sta 10+00
Sta 15+00
Sta 20+00
Sta 25+00
Sta 50+00
Sta 53+00
DIKE
CONCRETE WALL
STOPLOG BARRIER
PRESSURE CONDUIT
48" PC
36" PC
CITY OF WARWICK
Second Ave
Third Ave
Fourth Ave
Elmwood
Heath Ave
Wingate
Sumner
King
Gould Ave
Warrington Ave
McLain Drive



NOTES

1. BUILDINGS SHOWN ARE THOSE EITHER INFLUENCING PROJECT ALIGNMENT, OR REQUIRING RELOCATION, OTHERS HAVE BEEN OMITTED
2. BUILDINGS SHOWN BY DASH LINES WOULD NEED TO BE RELOCATED OR PURCHASED IN FEE

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH

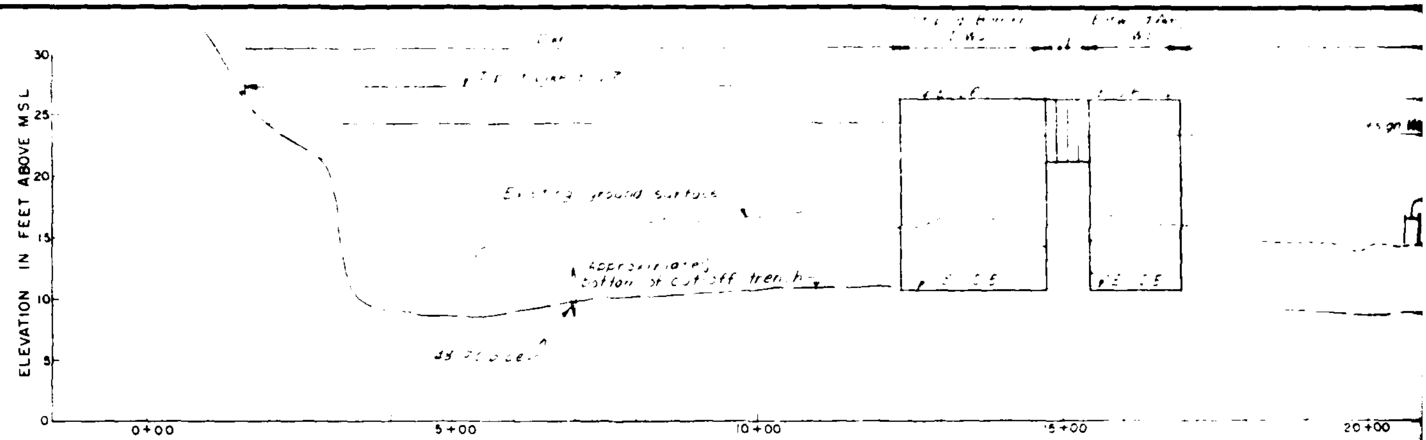
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
ELMWOOD AVENUE AREA
GENERAL PLAN

NORWOOD RHODE ISLAND

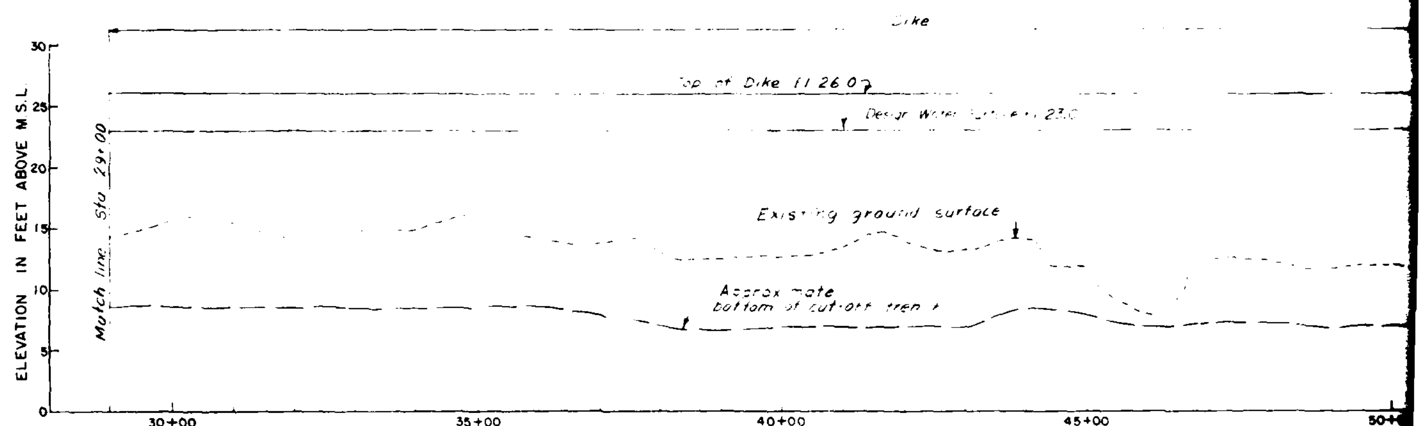
APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

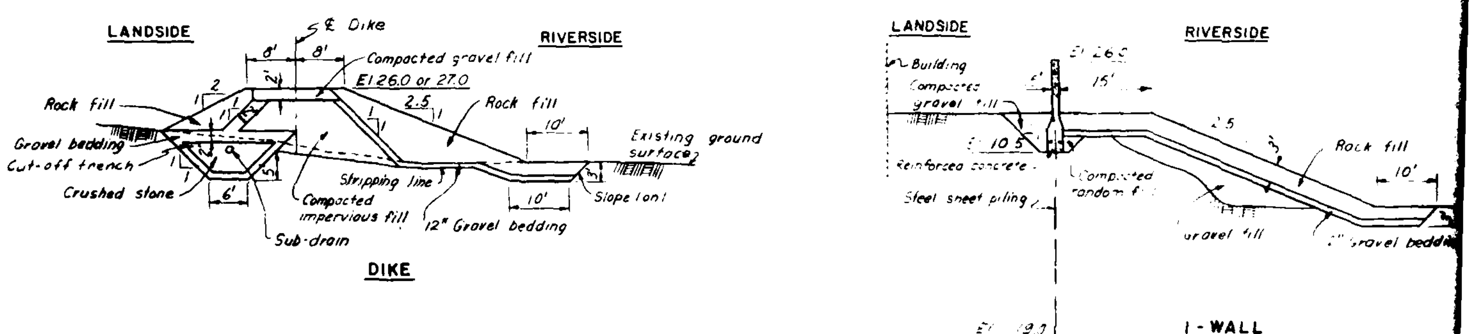
PLATE 16



℄ PROFILE
SCALE HOR 1" = 100' VERT 1" = 5'



℄ PROFILE (CONT.)
SCALE HOR 1" = 100' VERT 1" = 5'



TYPICAL SECTIONS
SCALE 1" = 10'

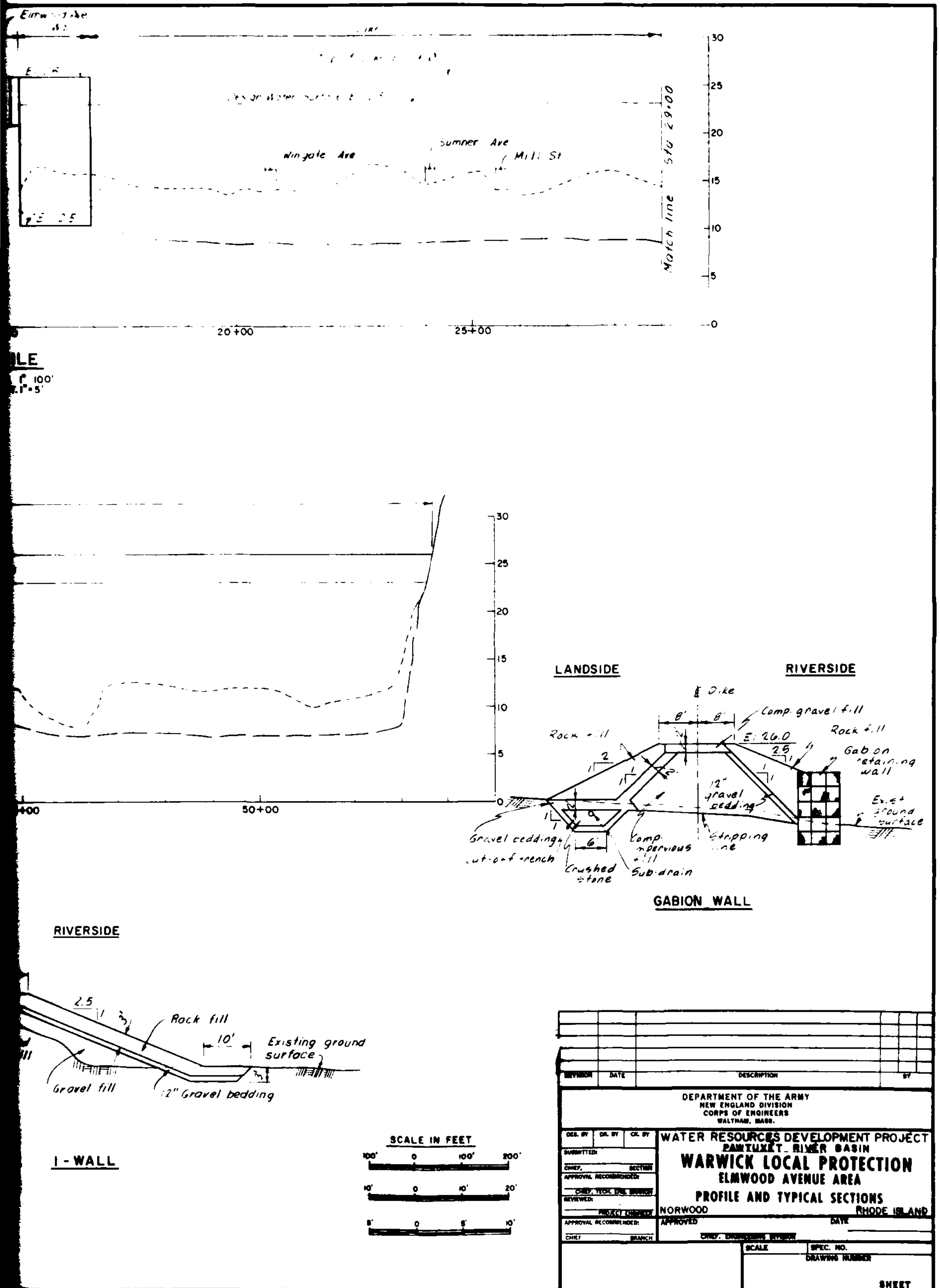

Sumner Ave
Wingate Ave
Mill St
Match line Sta 29+00
20+00
25+00
50+00
LE
LANDSIDE
RIVERSIDE
℄ Dike
Comp. gravel fill
Rock fill
E. 26.0
2.5
Gabion retaining wall
12" gravel bedding
Exist. ground surface
Gravel bedding
Cut-off trench
Crushed stone
Comp. impervious fill
Sub-drain
Stripping line
GABION WALL
RIVERSIDE
2.5
Rock fill
10'
Existing ground surface
Gravel fill
12" Gravel bedding
I - WALL
SCALE IN FEET
100' 0 100' 200'
10' 0 10' 20'
5' 0 5' 10'
REVISION
DATE
DESCRIPTION
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
ELMWOOD AVENUE AREA
PROFILE AND TYPICAL SECTIONS
NORWOOD
RHODE ISLAND
APPROVED
DATE
SCALE
SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 17

SUPPLEMENTAL

HYDROLOGIC ANALYSIS

FOR

PAWTUXET RIVER FLOOD CONTROL

Hydrologic Engineering Section
Water Control Branch
Engineering Division

New England Division, Corps of Engineers
Waltham, Massachusetts

November 1977

SUPPLEMENTAL
HYDROLOGIC ANALYSIS
FOR
PAWTUXET RIVER FLOOD CONTROL

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SUPPLEMENTAL HYDROLOGIC ANALYSIS FOR PAWTUXET RIVER FLOOD CONTROL

1. PURPOSE AND BACKGROUND

This report presents hydrologic information and analysis supplemental to that contained in a July 1975 report entitled: "Pawtuxet River Flood Control - Hydrologic Analysis", which was later distributed under the title: "Planning Aid Report - Hydrologic Analysis". The original report presented data, description and hydrologic engineering analysis relative to a comprehensive flood control plan for the lower Pawtuxet River. The comprehensive plan included a facility for diverting floodflows via tunnel from the Pawtuxet River in Natick to the ocean at Apponaug Cove in Greenwich Bay. This diversion would have provided a high degree of flood control along the lower 10 miles of the highly developed reach of the river. A second feature of the comprehensive plan involved the construction of walls and dikes in Warwick, near the mouth of the river, to protect an industrial and residential area against residual tidal and riverine flooding.

The comprehensive plan as proposed by the Corps of Engineers was not well received by the public due mainly to the massiveness of the plan, the overall cost, and possible environmental impact of the diversion on the receiving waters of Greenwich Bay.

This supplemental report concerns a compromise plan which deletes the Natick diversion and consists only of the Warwick local protective works built to the higher elevation required by deletion of the upstream diversion. As an added feature the compromise plan would include flood control storage, in addition to water supply storage, in "Big River", a water supply reservoir planned by the State of Rhode Island at a site in the South Branch watershed of the Pawtuxet River basin.

All hydrologic description, climatology and analysis of floods presented in the original report remains relevant. This report presents only supplemental hydrologic analysis pertinent to the compromise plan. Included are sections on the Big River reservoir, the Warwick local protection projects, and other pertinent discussion.

All hydrologic analyses performed has been of general scope intended only as a general base for conceptual planning, costing, and initial decision making. More detailed analysis would be required in any final design.

2. BIG RIVER RESERVOIR

a. General. Big River reservoir, as planned by the State of Rhode Island, will be constructed on the Big River, a tributary to the South Branch of the Pawtuxet River. It will be a water supply reservoir, interconnected with, and supplementing the existing Providence regional water supply system. It is intended that waters

will be diverted, during high flow seasons, from the Wood River in the Pawcatuck River basin and the Moosup River in the Thames River basin to the Big River storage. The Big River storage will, in turn, divert to the existing Scituate Reservoir located on the North Branch of the Pawtuxet. Lands for the project have been purchased by the State and preliminary engineering is complete. Dates for the initiation of final design and construction are indefinite.

b. Pertinent Data. Following is a list of pertinent data on the Big River Reservoir, as planned by the State of Rhode Island. Location of the project is shown on plate 1. With a contributing watershed of 29.7 square miles and a pool area of 3,500 acres, flood control storage equivalent to 6 inches of runoff from the watershed can be provided by raising the spillway crest by about 2.7 feet to elevation 302.7 feet msl. Top of dam would be raised accordingly from 310 to 313 feet msl.

PROPOSED
BIG RIVER RESERVOIR
PERTINENT DATA

Location:	West Greenwich, Rhode Island
Drainage area:	29.7 square miles
Water supply storage:	86,500 acre-feet
Water supply pool elevation:	300 feet msl
Full pool surface area:	3,500 acres
Approximate height of dam:	70 feet
Top of dam for water supply:	310 feet msl
Spillway length:	400 feet
Full pool with flood control:	302.7 feet msl
Flood control storage:	9,500 acre-feet
Spillway crest:	302.7 feet msl
Design surcharge:	5.3 feet
Freeboard:	5.0 feet
Top of dam with flood control:	313 feet msl

c. Flood Reductions. Providing 9,500 acre-feet of flood control storage in Big River reservoir will be sufficient to control flood runoff from its 29.7 square mile watershed; however, the watershed controlled represents only about 12 percent of the total Pawtuxet River watershed, therefore, resulting flood reductions on the main stem Pawtuxet are quite limited. The potential reduction will vary depending on the type of flood development, antecedent conditions, and the storm orientation over the basin. Table 1 lists the representative percent reductions in floodflows provided by Big River at selected index stations on the South Branch and main stem Pawtuxet River. Reductions in the March 1968, July 1938 and standard project flood by Big River reservoir are presented in table 2. Natural peak discharge frequencies, taken from the previous hydrologic report are shown in table 3, and on plate 2. Development of the March 1968 flood and the standard project flood are shown on plates 3 and 4, respectively. A profile of the South Branch of the Pawtuxet River is shown on plate 5.

TABLE 1

TYPICAL PERCENT
REDUCTIONS IN FLOODFLOWS
BY BIG RIVER RESERVOIR

Location	Drainage Area (square miles)	Percent Reduction
South Branch at Washington Gage	63.8	50
Natick Dam	180	25
Cranston USGS gage	200	20
Warwick Avenue	228	10

TABLE 2

EFFECTS OF BIG RIVER RESERVOIR

Location	Drainage Area (sq mi)	March 1968 Flood Natural Q (cfs)	March 1968 Flood Natural Elevation (ft msl)	March 1968 Flood Modified Q (cfs)	March 1968 Flood Modified Elevation (ft msl)	July 1938 Flood Natural Q (cfs)	July 1938 Flood Natural Elevation (ft msl)	July 1938 Flood Modified Q (cfs)	July 1938 Flood Modified Elevation (ft msl)
South Branch at Washington Gage	63.8	1,870	224.0	900	222.5	-	-	-	-
At Natick Dam	180	2,600	33.4	1,550	31.5	5,800	37.6	4,900	36.6
At Cranston USGS Gage	200	3,110	19.7	2,340	18.2	6,300	22.7	5,350	21.9
At Warwick Avenue	228	3,900	12.0	3,500	11.6	7,000	[illegible].4	6,100	13.8

Location	Drainage Area (sq mi)	100-Year Frequency Flood Natural Q (cfs)	100-Year Frequency Flood Natural Elevation (ft msl)	100-Year Frequency Flood Modified Q (cfs)	100-Year Frequency Flood Modified Elevation (ft msl)	Standard Project Flood Natural Q (cfs)	Standard Project Flood Natural Elevation (ft msl)	Standard Project Flood Modified Q (cfs)	Standard Project Flood Modified Elevation (ft msl)
South Branch at Washington Gage	63.8	2,750	225.0	1,470	223.4	7,900	228.7	4,250	226.3
At Natick Dam	180	5,500	37.4	4,100	~~31.8~~ 35.6	17,000	46.9	13,600	44.2
At Cranston USGS Gage	200	6,600	23.0	5,300	21.8	19,600	32.8	16,200	30.5
At Warwick Avenue	228	8,200	15.2	6,900	14.4	23,000	21.3	20,700	20.6

TABLE 3

DISCHARGE FREQUENCY DATA

	South Branch Pawtuxet River Washington, R.I.	Branch River Blackstone Basin Forestdale, R.I.	Kettle Brook Blackstone Basin Worcester, Mass.	Adopted for[1] Local To Cranston Gage	Adopted for[1] Local Below Cranston
Drainage Area (sq mi)	63.8	91.2	31.3	50.5	30.4
Log of Mean	2.81	3.19	2.65	3.05	2.82
Standard Deviation	0.216	0.220	0.325	0.270	0.250
Adopted Skew	+0.5	+0.5	+0.5	+0.50	+0.50
100-Year Frequency (Q in cfs)	2,750	6,600	3,620	6,000	3,000
50-Year Frequency "	2,200	5,300	2,690	4,600	2,500
20-Year Frequency "	1,600	3,950	1,790	3,300	1,800
10-Year Frequency "	1,300	3,100	1,270	2,500	1,400
5-Year Frequency "	950	2,400	850	1,800	1,050
2-Year Frequency "	620	1,480	420	1,100	640

(1) Peak runoff to river reach from all intervening local area. Not necessarily peak contribution to river outflows pending initial and concurrent riverflow conditions.

3. MODIFIED WARWICK LOCAL PROTECTION

a. Warwick Avenue Area

(1) General. The compromise plan for protective works along the Pawtuxet River in the Warwick Avenue area remains conceptually the same as that for the comprehensive flood plan, except, the height of protection has been raised. This increase in height was necessary to provide protection against the larger standard project flood resulting with a deletion, from the plan, of the upstream Natick diversion. A plan of the Warwick Avenue area is shown on plate 6.

(2) Design discharge. The protective works at Warwick Avenue would be designed to protect against a peak Pawtuxet flow of 20,000 cfs. This is the resulting standard project flood discharge after modification of the natural peak of 23,000 cfs by the planned Big River project. The new SPF flow, as modified by Big River, is 57 percent greater than the SPF flow as modified by the Natick diversion proposed in the original comprehensive flood control plan.

(3) Profiles. Flood profiles were computed, as described in the original hydrologic analysis report, using a minimum of surveyed cross sections in the HEC-2 computer program. Backwater computations were made using a Manning's "n" of 0.05 for channel and 0.08 for overbank. Assumed contraction and expansion loss coefficients were 0.3 and 0.5, respectively.

Computed river profiles for various flood conditions including design water surface are illustrated on plate 9. The design water surface profile is also shown on plates / and 8.

(4) Velocities. Under design flood conditions, with the Warwick Avenue local protective works in place, maximum flow velocities would be in the order to 6 to 8 feet per second. These maximum velocities would occur with a design discharge in the river and a normal tide in the bay. The riverward side of earthen dikes would be riprap protected for a tractive force of about 0.7 lb/ft^2, resulting from maximum design velocities. Though tractive forces are low, the adopted D_{50} minimum will not be less than 1.0 foot.

(5) Freeboard. Earthen dikes and concrete walls would be designed to provide 3 feet and 2 feet of freeboard, respectively. Freeboard is the vertical distance from the computed design water surface to the top of protective works, and is provided to protect against uncertainties and unaccounted factors in the computation of the design profile. Less freeboard is provided with concrete walls due to their greater resistance to failure if some overtopping should occur. Building walls slightly lower than the dikes also permit overtopping of walls before dikes, thereby serving as a relief valve in the event of a flood greater than design.

(6) Height of protection. The height of protection required to protect against a standard project floodflow, as modified by Big River reservoir, is shown on plates 7 and 8. The

level of protection was based on protecting against the severest of either: (a) the SPF riverflow with a 100-year storm tide or (b) a standard project tidal backwater in the reach. A standard project riverflow coincident with a standard project tide was considered too remote for design.

The present plan of protection in the Warwick Avenue area is about 2 feet higher at the downstream end and 4 feet higher at the upstream end, than the height of protection originally required in the comprehensive flood control plan with the upstream Natick diversion.

(7) Interior drainage. The plan of protective works for the Warwick Avenue area would intercept interior runoff from a total of 710 interior acres. This total is comprised of subareas 1, 2, and 3 with areas of 110, 150, and 450 acres, respectively. For costing purposes it was assumed that one pumping station would serve subareas 1 and 2 and a second station would be installed to discharge runoff from subarea 3 during flood periods. Subarea 3 consists of 450 acres of watershed lying south of the Boston Post Road which outlets to the Pawtuxet River near the downstream end of the proposed line of protection. It is now believed that, in any final design a refinement may be possible, whereby the line of protection can be "wrapped around" at the downstream end and tied into high ground along the north side of the drainage outlet from subarea 3. Such a refinement would thus eliminate the need for the 100 cfs pumping station 3. This refinement appears both practical and feasible and would be pursued further in any final design, however,

for present costing analysis the pumping station has been retained.

Subareas 1 and 2, as described in the earlier hydrologic analysis report are located adjacent to the river and are very flat and low in elevation with respect to the normal river level. High rates of runoff are not experienced from these areas due to their flat gradients and puddling occurs throughout the areas during intense rainfall. Such temporary ponding of interior drainage must be expected and provided for under future improved conditions. To accomplish this a low area along the toe of the dike would be regraded and preserved for temporary ponding and it would be specified in local assurances that no building be allowed in the protected area with first floor grades below elevation 12.0 feet msl. This zoning will prevent serious flood damages during very infrequent more extensive ponding. Minimum elevations in the protection area would be about elevation 8.0 feet msl and approximately 60 acre-feet of storage could take place between elevations 8 and 12 feet msl. Though it might appear that ponding capacity was adequate for the control of interior runoff, an 80 cfs pumping station has been included to prevent the need for long term ponding of interior runoff because of the lowness of the area with respect to the river. The adopted 80 cfs pump capacity is equivalent to a runoff rate of about one-third inch per hour from the 260 acre interior area. More detailed studies would be required in final design to determine the optimum combination of pump size and land takings for ponding, how-

ever, the selected plan is considered adequate for costing purposes and conceptual planning.

b. Elmwood Avenue Area

(1) General. The plan for the Elmwood Avenue segment of the Warwick local protection project remains basically unchanged, except that a considerably higher level of protection is required with the abandonment of the comprehensive upstream Natick diversion plan.

(2) Design discharge. The Elmwood Avenue area, shown on plate 10, will be protected against a design flow in the Pawtuxet of 18,500 cfs, which is the SPF flow, as modified by Big River reservoir. The natural SPF without Big River is 21,300 cfs. The current design flow of 18,500 cfs is 55 percent greater than the original residual flow with the contemplated Natick diversion plan.

(3) Profiles. Profiles for the Elmwood area shown on plate 11 were computed by backwater using the same procedure as for the Warwick area. The methodology for profile determination is discussed under paragraph 3a(3) of this report as well as in the original Hydrologic Analysis report. Computed river profiles for various flood conditions including a design water surface profile are illustrated on plate 9.

(4) Velocities. Velocities in the river under present design flow conditions will be in the order of 5 to 7 feet per second. All exposed earthen dikes will be riprap protected

against a resulting design tractive force of 0.7 lb/ft^2. Though tractive forces are low the adopted D_{50} minimum will not be less than 1.0 foot.

(5) Freeboard. Freeboard criteria at Elmwood would be the same as the Warwick Avenue area which is discussed in paragraph 3a(5) of this report.

(6) Height of protection. The abandonment of the upstream Natick diversion concept has a marked effect on the design flow at Elmwood and as a result requires a considerable increase in height of protection. Required increases in height of protection vary from about 4 feet at the downstream end of the protective works to 5 feet at the upstream end. Present design heights of protection are indicated on plate 11.

(7) Interior drainage. The protective works in the Elmwood Avenue area would intercept interior drainage from about 150 acres. As discussed in the original hydrologic analysis report, it is contemplated that runoff from about 85 acres or 60 percent of the area can be intercepted and conveyed to the river via pressure conduit. The remaining drainage will be intercepted along the line of protection and conveyed to a pumping station for discharge to the river during flood periods. Gated gravity outfalls will be provided for discharge during normal periods. Gravity outfalls would be designed for a 100-year frequency storm runoff.

The pumping station for the Elmwood Avenue area was sized at 105 cfs for costing and planning purposes. This capacity is equivalent to a runoff rate of 0.6 inch per hour from the residual 65 acres of low level area. As stressed in comments from OCE, dated 21 March 1977, more extensive studies would be required in any final design to determine the optimum pump size versus interior ponding to be permitted. Such studies would require further land surveys to better establish the interior stage-storage capacity characteristics. However, much of the flood prone properties are residential in which flood damages would be extensive with any appreciable ponding. It has therefore been concluded that extensive ponding would not be permissible and a pumping station must be included as an integral component of any local protective works considered for the area.

4. DISCUSSION

a. General. Flood control on the Pawtuxet River has long been a subject of varying opinions relating to economic, social, environmental as well as hydrologic considerations. This compromise plan of improvement is the result of many often opposing opinions. Some of the more pertinent hydrologic features of this plan as well as other plans considered, are briefly discussed in the following paragraphs.

b. Limitations of Compromise Plan. The compromise Pawtuxet River flood control plan would provide a high degree of protection to two localized areas totaling approximately 200 acres of flood prone land. One being a commercial-industrial park area and the other highly residential. The plan further recommends including flood control storage in the future Big River water supply reservoir. However, it must be stressed that flood reductions provided by this storage in the lower Pawtuxet basin are quite limited, generally less than one foot. Therefore caution must be exercised to prevent the populace of the flood plain, outside the protected areas, from adopting a false sense of security. Reductions in flow and stage attributable to Big River are ahown in table 2 and plate 9.

c. Effects of Improvements. The dikes and walls of the compromise plan will be designed for a significantly greater flow, than with the comprehensive plan, where local protection was required only for residual flows downstream of the then proposed Natick diversion.

With greater flows the dikes and walls will pose some hydraulic impedance to overbank flows during major floods approaching standard project magnitude. The greatest effect, flood stagewise, would be about a 0.5 foot rise in SPF stage at the upstream end of the Elmwood Avenue protective works. Since the Big River reservoir would reduce the natural SPF at this location by approximately 0.5 foot and the protective works would increase the modified SPF by

about 0.5 foot, the net effect of both the reservoir and protective works would be near zero at the upstream end of the protective works. The effect of the dikes on river stage would diminish moving upstream and be negligible above the USGS gage in Cranston.

d. Compatability of Plan. The compromise plan consists of flood control storage in Big River and local protection in the Warwick and Elmwood Avenue areas. Though the three components are one system, they are not entirely interdependent. For example, if Big River reservoir is delayed or never built, the local protection projects, as planned, would provide protection against a flow 88 percent of the natural standard project flood, which, though not complete, would be an acceptable project on its own. Similarly, the Warwick Avenue and Elmwood Avenue projective works, though nearly contiguous, are hydrologically not inseperable or interdependent in any way.

e. Other Improvements Considered

(1) Scituate flood control. Scituate Reservoir, located on the North Branch of the Pawtuxet, has a drainage area of 92 square miles and a full pool surface area of 3,400 acres. The idea of providing flood control on the Pawtuxet River by either reregulating or adding storage at Scituate has risen many times over the years; however, it is noted that Scituate already provides a high degree of control over its watershed. During many freshets the entire runoff from its watershed is stored in Scituate.

Depending on antecedent storage capacity, and during other events where the pool is at or nearly full, surcharge storage in the large lake has served to greatly modify and desynchronize the runoff from its watershed. The effect of Scituate on flood runoff in past floods is presented in table 7 of the original hydrologic analysis report. It is not to be inferred that Scituate is an automatic panacea. The July 1938 flood illustrated that Scituate outflow could be a significant flood component. Therefore, optimum regulation procedures should be employed at the project to maximize flood control potential while not infringing on dependable water supply yield.

However, complete control at Scituate would not entirely alleviate the flood potential on the main stem Pawtuxet and costly modification to Scituate is not considered feasible. Much of the existing flood potential results from the uncontrolled watershed downstream of Scituate. Protection would still be needed against residual freshwater flooding and tidal flooding in the Warwick area. For example, with complete flood control at Scituate the standard project flood at Warwick Avenue, as modified by Big River, would be further modified to 18,400 cfs with flood control at Scituate. This modification would not eliminate the need for protection but would serve only to reduce the required height by about 1 foot. The effect of control at Scituate on the standard project flood is shown on plate 12.

(2) Removal of dams. There are numerous small "run-of-river" dams throughout the Pawtuxet basin. It has been suggested that removal of some of these dams would reduce floodflow gradients, thereby reducing flood damages. The dam most often mentioned is the Broad Street dam situated at the mouth of the Pawtuxet. Backwater studies have been performed to determine the effects of complete removal of this dam. During a standard project riverine flood the flood stage would be reduced about 7 feet at the dam and this reduction would diminish upstream becoming insignificant at Warwick Avenue. Removal of this dam would have the associated impacts of: (a) returning the lower Pawtuxet to a tidal estuary with its resulting environmental impact, and (b) normal riverflow velocities would be increased causing possible bank erosion problems if protective measures were not provided. Most importantly, however, removal of the dam would do nothing to protect the lower Pawtuxet against the existing threat from tidal flooding, and its removal could create a "false sense of security" with respect to flood control.

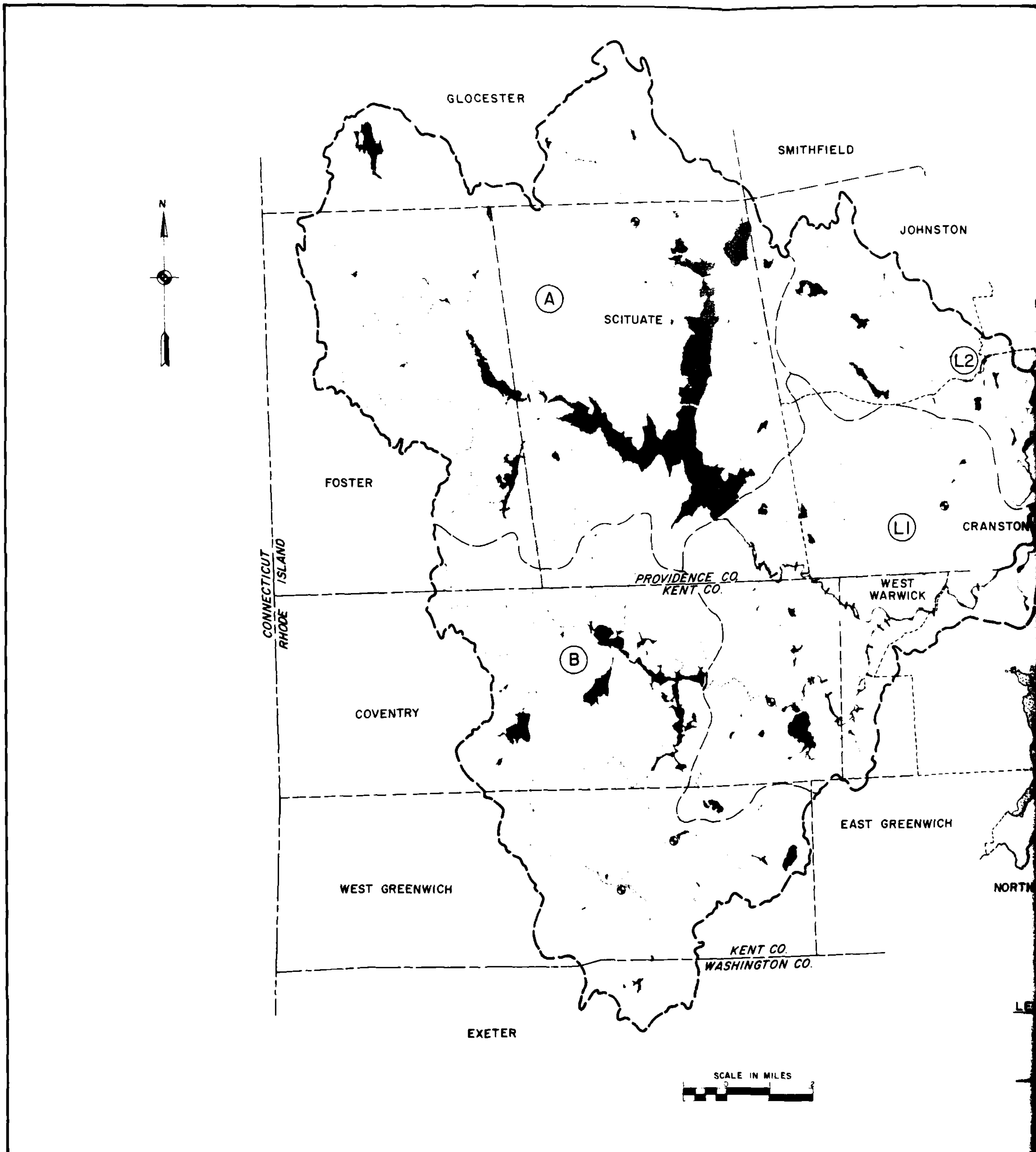
As the Broad Street dam becomes deteriorated, its repair or removal should be based largely on environmental considerations. Flood control benefits to be gained by its removal would be small, relative to the other considerations discussed above, and Federal involvement is not considered warranted.

A second dam on the lower mainstem Pawtuxet is the Pontiac dam. Its removal would have a reducing effect on flood levels just upstream. The effect of the removal of this dam on the standard project and the 100-year frequency flood levels are shown on plate 13. Presently there is little flood prone development just upstream of the dam and its normal backwater pool does have esthetic appeal. However, in the future if the dam needs major repair, removal may have to be considered. If removed, upstream measures may be needed to protect against scour and excessive degradation.

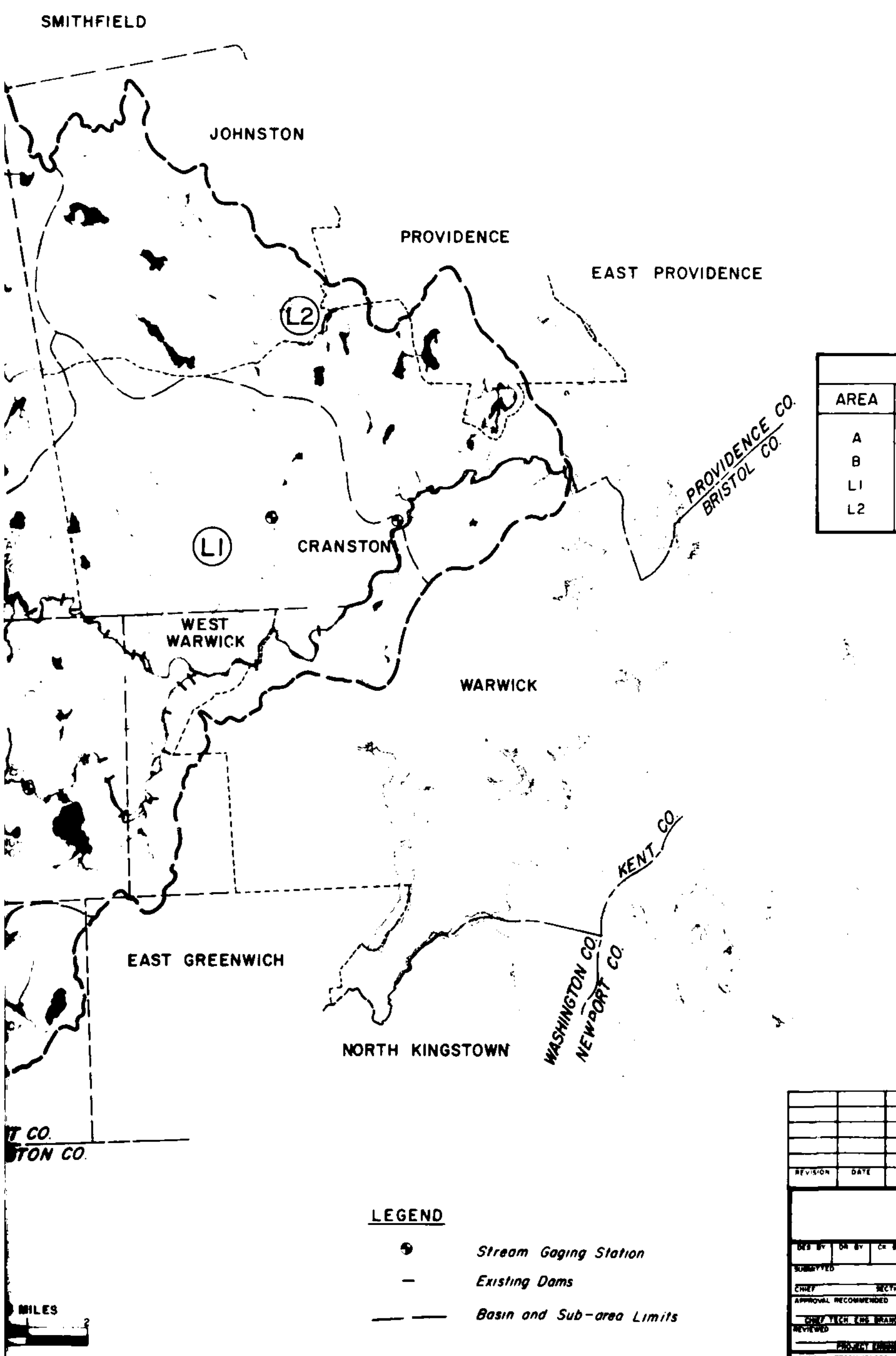
The majority of the other dams are low head, becoming submerged by backwater during floods or have minimal, if any, flood prone property near the dams.

(3) Channel improvement. It has been suggested by some that flood control on the lower Pawtuxet should and could be accomplished by clearing the channel of debris and obstructions, i.e., channel improvement. First, it is stated that such improvements would only have an effect on riverine flooding and no effect on tidal flooding in the lower basin. Secondly, localized obstructions generally have a localized effect. Therefore, effective channel improvements would consist of enlarging the channel through deepening and widening. Such improvements would require riprap protection of exposed banks and due to the cost of bridge modifications, the proposal is deemed impractical, particularly since the threat of tidal flooding would remain.

Profiles illustrating the potential effect of dam removal and channel improvement in the lower Pawtuxet River, for both the standard project and 100-year floods, are shown on plate 13.



GLOCESTER
SMITHFIELD
JOHNSTON
N
A
SCITUATE
L2
FOSTER
L1
CRANSTON
CONNECTICUT
RHODE ISLAND
PROVIDENCE CO.
KENT CO.
WEST WARWICK
B
COVENTRY
EAST GREENWICH
WEST GREENWICH
KENT CO.
WASHINGTON CO.
EXETER
SCALE IN MILES



LOCATION MAP

SCALE IN MILES
0 10 20 30 40 50

BASIN SUB-DIVISIONS

AREA	DESCRIPTION	DRAINAGE AREA SQUARE MILES
A	Scituate Reservoir	92.8
B	Flat River Reservoir	56.7
L1	Local to USGS Gage Cranston	50.5
L2	Local From Cranston Gage to Mouth	30.4

LEGEND

- Stream Gaging Station
- Existing Dams
- Basin and Sub-area Limits

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

DES BY / DR BY / CH BY
SUBMITTED
CHIEF SECTION
APPROVAL RECOMMENDED
CHIEF TECH ENG BRANCH
REVIEWED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

PAWTUXET RIVER BASIN

WATERSHED MAP

PAWTUXET RIVER — RHODE ISLAND

APPROVED — DATE

CHIEF ENGINEERING DIVISION

SCALE — SPEC NO — DRAWING NUMBER

SHEET

PLATE I

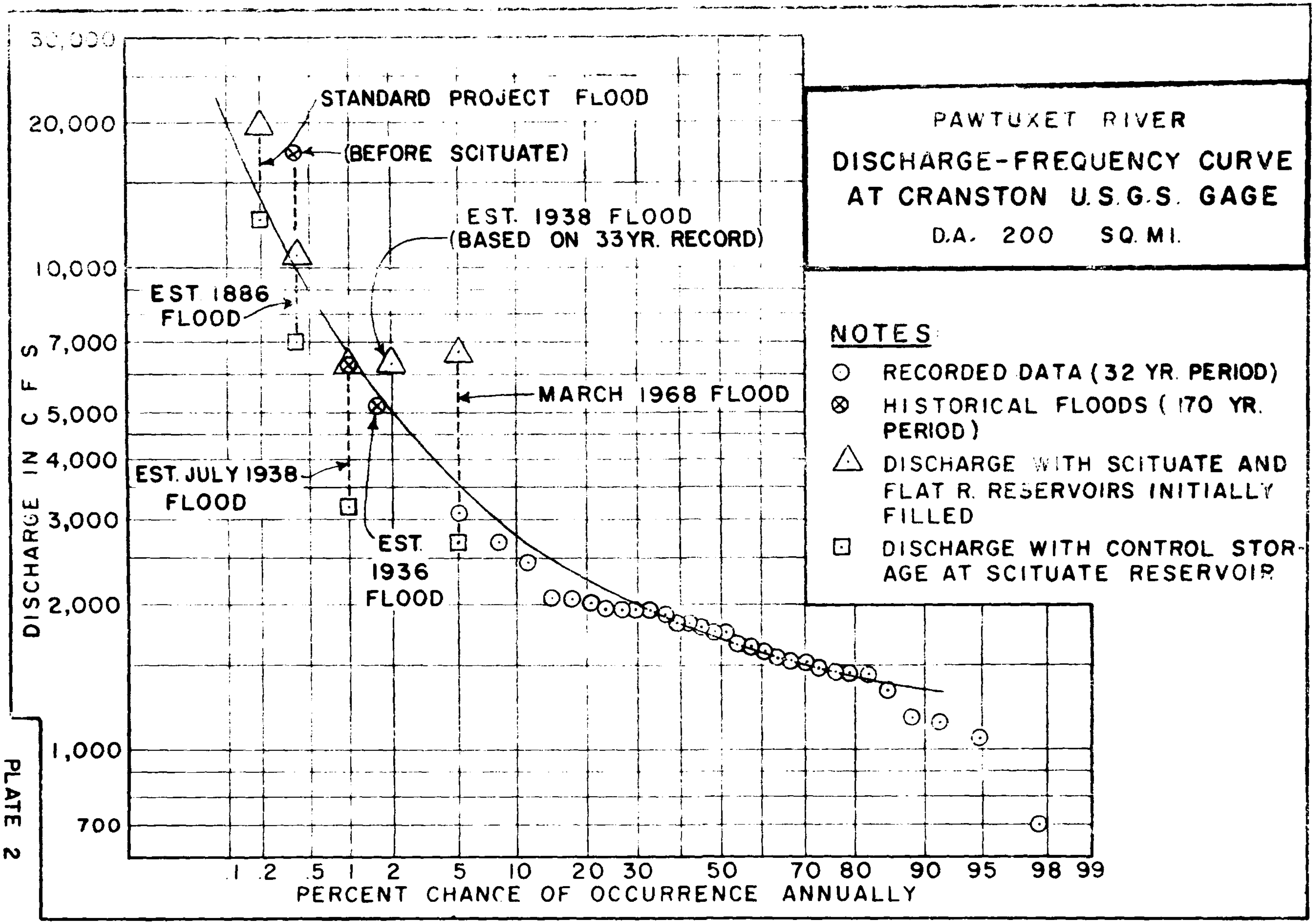
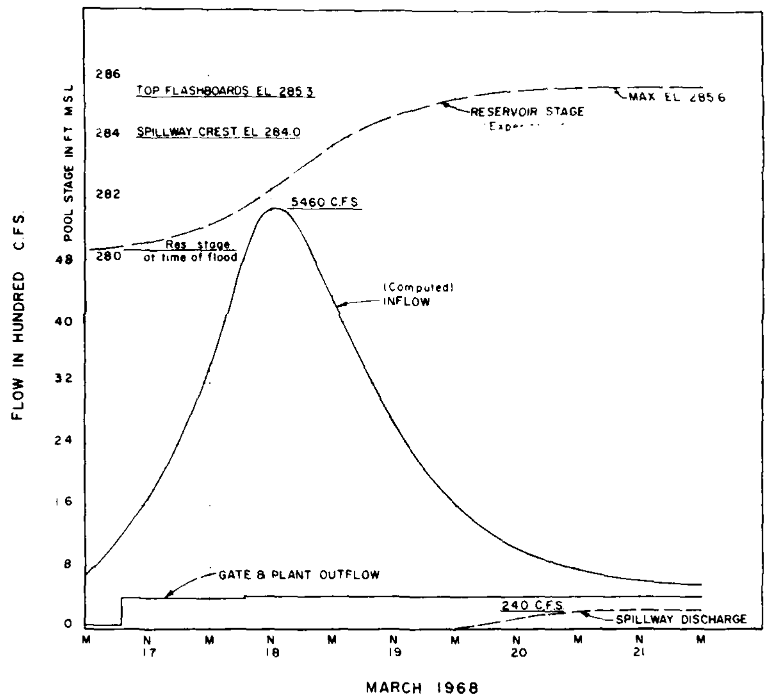
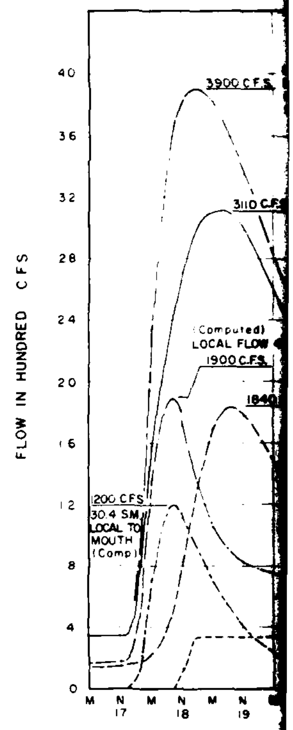

PAWTUXET RIVER
DISCHARGE-FREQUENCY CURVE
AT CRANSTON U.S.G.S. GAGE
D.A. 200 SQ. MI.
NOTES
RECORDED DATA (32 YR. PERIOD)
HISTORICAL FLOODS (170 YR. PERIOD)
DISCHARGE WITH SCITUATE AND FLAT R. RESERVOIRS INITIALLY FILLED
DISCHARGE WITH CONTROL STORAGE AT SCITUATE RESERVOIR
STANDARD PROJECT FLOOD
(BEFORE SCITUATE)
EST. 1938 FLOOD
(BASED ON 33YR. RECORD)
EST 1886 FLOOD
MARCH 1968 FLOOD
EST. JULY 1938 FLOOD
EST. 1936 FLOOD
DISCHARGE IN C F S
30,000
20,000
10,000
7,000
5,000
4,000
3,000
2,000
1,000
700
.1 .2 .5 1 2 5 10 20 30 50 70 80 90 95 98 99
PERCENT CHANCE OF OCCURRENCE ANNUALLY

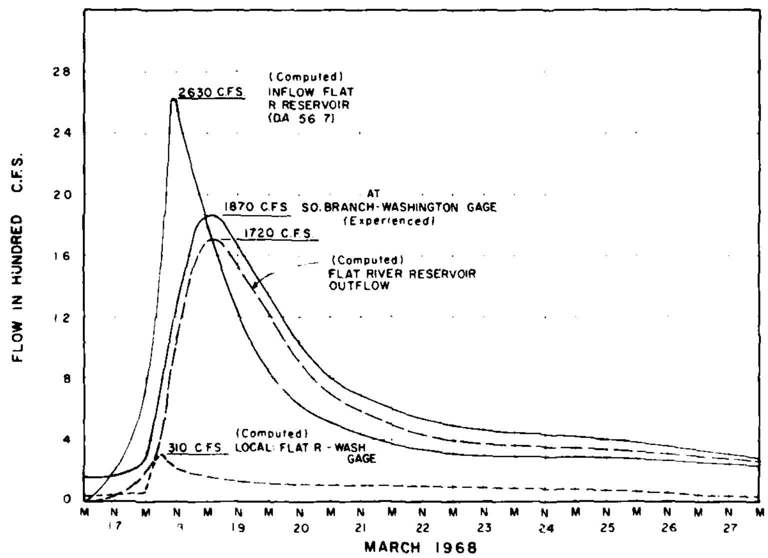
PLATE 2



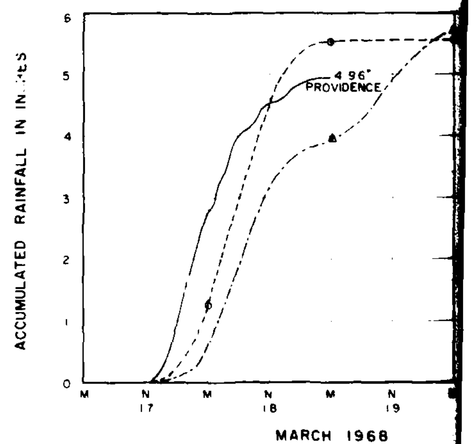
SCITUATE RESERVOIR
(DA 92.8 Sq. Mi.)



FLOOD CO

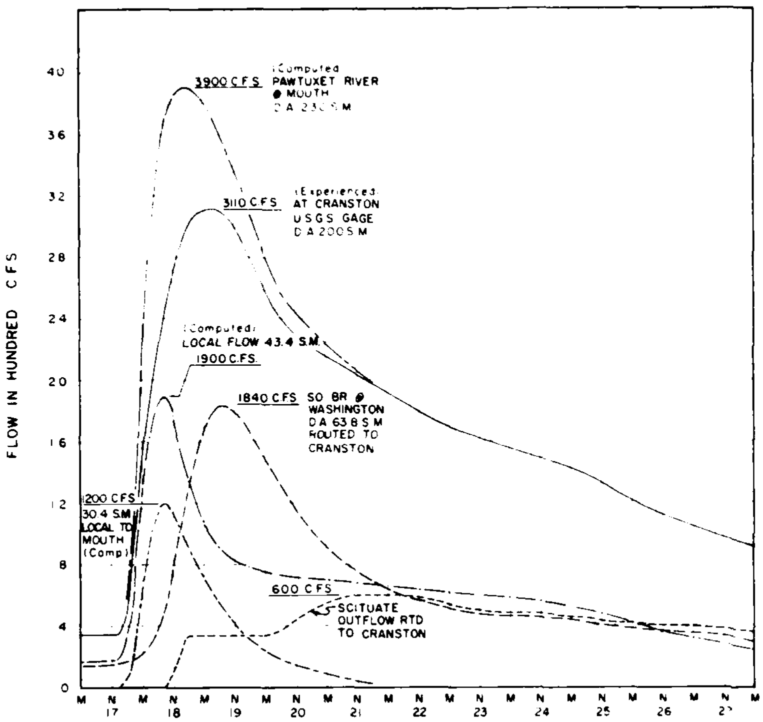


SOUTH BRANCH PAWTUXET RIVER
AT
WASHINGTON R.I. (DA 63.8 Sq. Mi.)



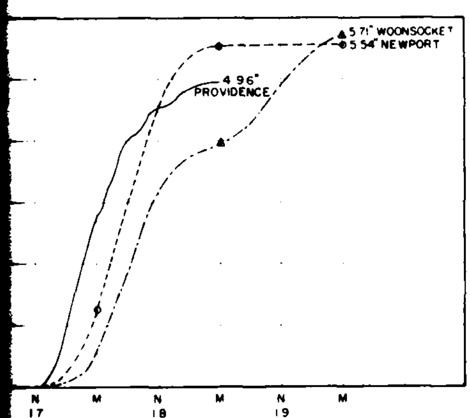
MASS RAINFALL CURVES

(⊙, △ INDICATE OBSERVED RAINFALL



MARCH 1968

FLOOD COMPONENTS AT CRANSTON USGS GAGE AND AT MOUTH OF PAWTUXET RIVER



MARCH 1968

MASS RAINFALL CURVES

(●, △ INDICATE OBSERVED RAINFALL VALUE)

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

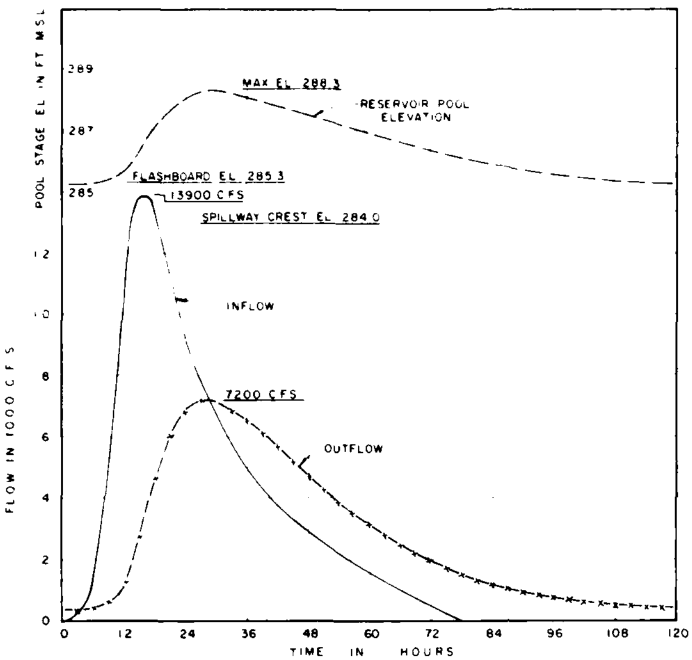
WATER RESOURCES DEVELOPMENT PROJECT

PAWTUXET RIVER BASIN
MARCH 1968 FLOOD
ANALYSIS

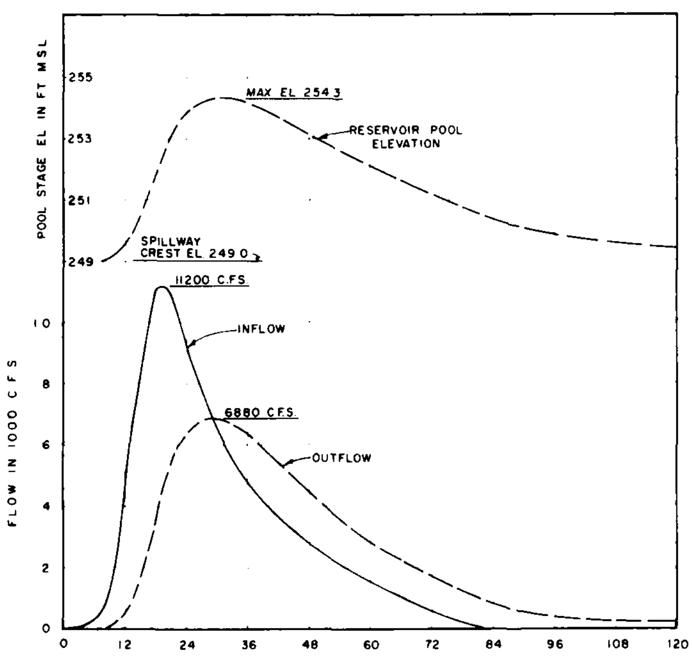
PAWTUXET RIVER RHODE ISLAND

DES. BY	DR. BY	CK. BY
SUBMITTED:		
PROJECT ENGINEER		
APPROVAL RECOMMENDED:	APPROVED	DATE
CHIEF BRANCH	CHIEF, ENGINEERING DIVISION	
	SCALE	DRAWING NUMBER

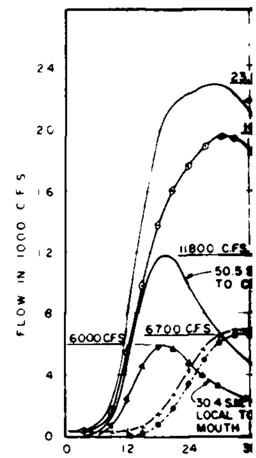
PLATE 3

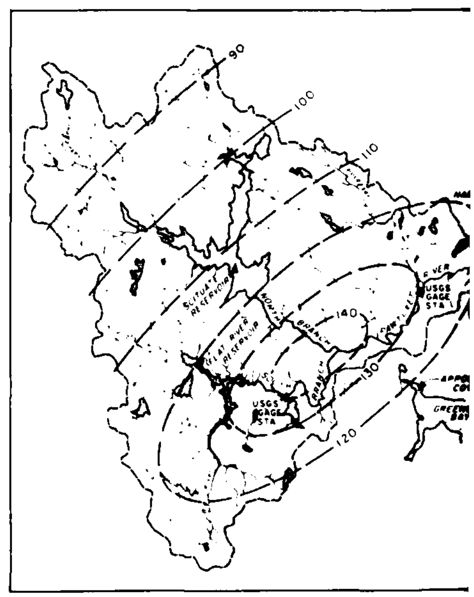


SCITUATE RESERVOIR



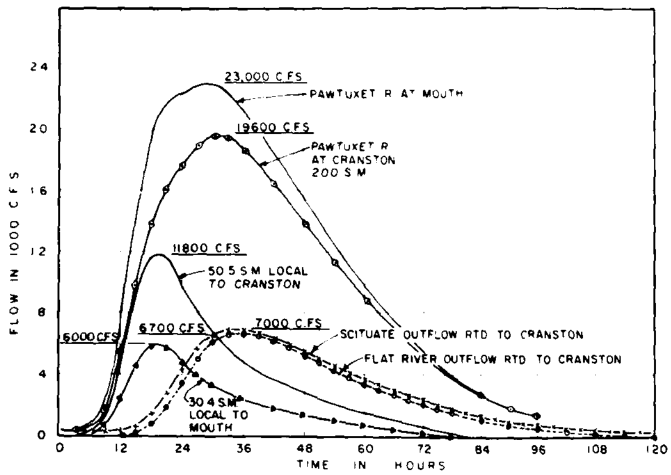
FLAT RIVER RESERVOIR



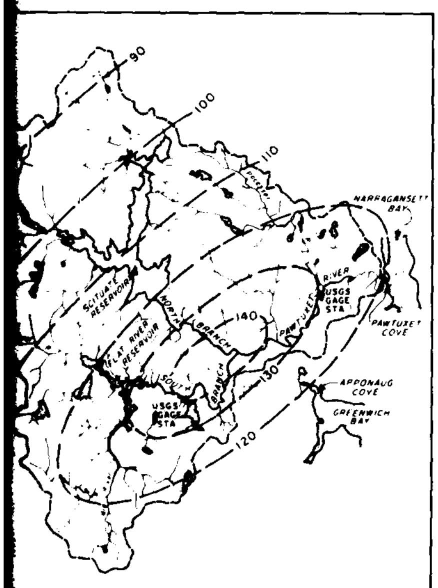


STANDARD PROJECT STORM

PATTERN IN PERCENT OF 96 HR-200 SQ. MILE INDEX RAINFALL



PAWTUXET RIVER BASIN



STANDARD PROJECT STORM
PATTERN IN PERCENT OF 96 HR-200
SQ. MILE INDEX RAINFALL

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DS. BY	DR. BY	CK. BY

SUBMITTED:

PROJECT ENGINEER

APPROVAL RECOMMENDED:

CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PROJECT

PAWTUXET RIVER BASIN

STANDARD PROJECT FLOOD

PAWTUXET RIVER RHODE ISLAND

APPROVED DATE

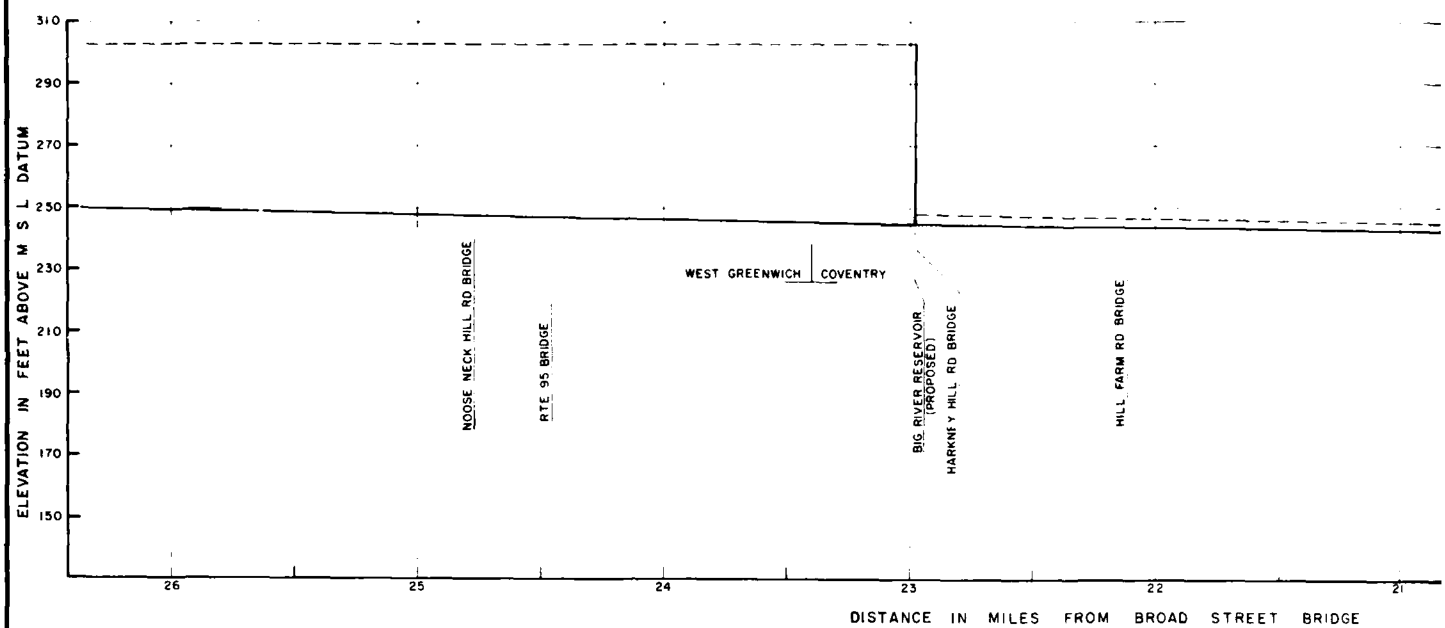
CHIEF, ENGINEERING DIVISION

SCALE

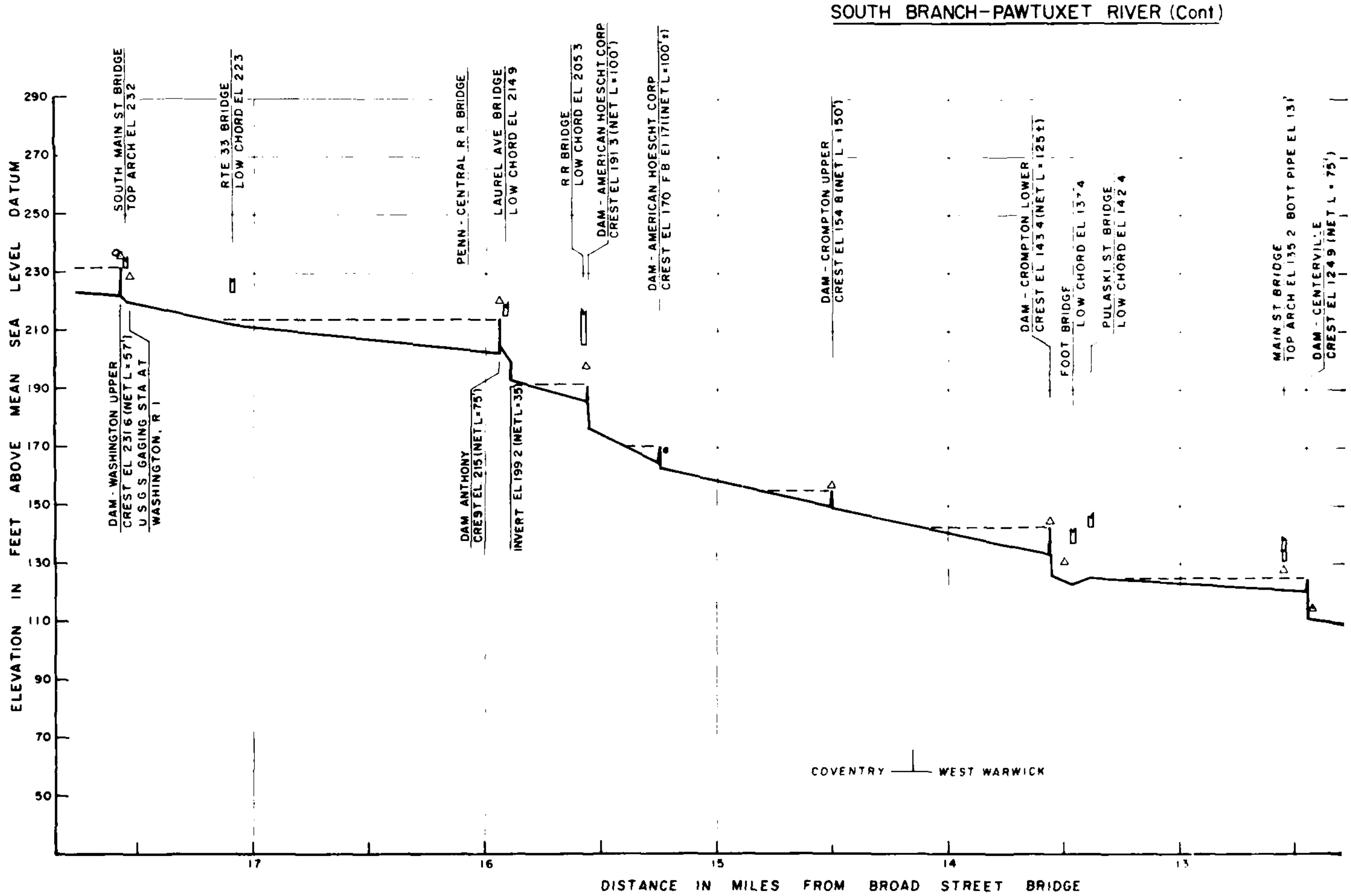
DRAWING NUMBER

SHEET

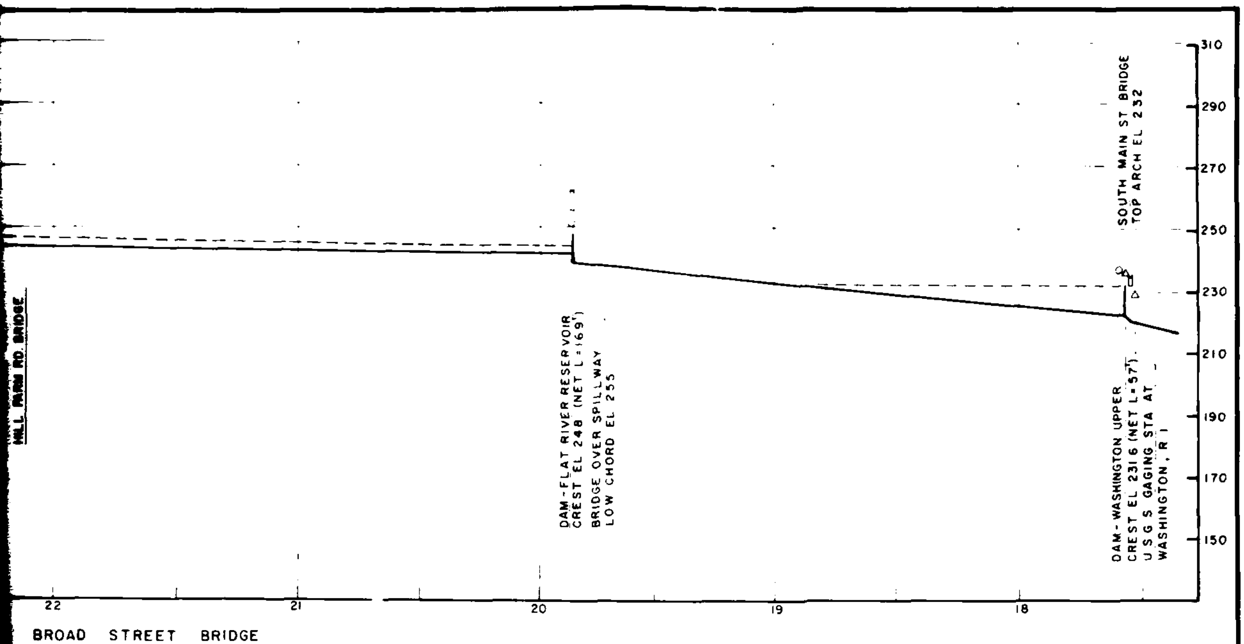
PLATE 4



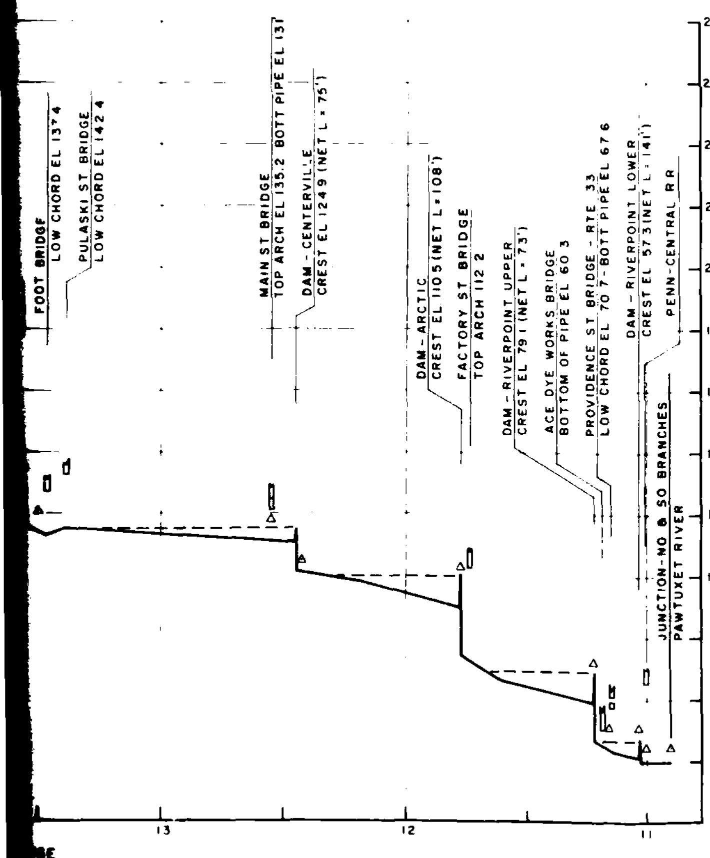
SOUTH BRANCH-PAWTUXET RIVER (Cont)



SOUTH BRANCH-PAWTUXET RIVER



UXET RIVER (Cont.)



LEGEND

△ HIGH WATER MARKS JULY 1938

○ HIGH WATER MARKS MARCH 1968

REVISION	DATE	DESCRIPTION	BY

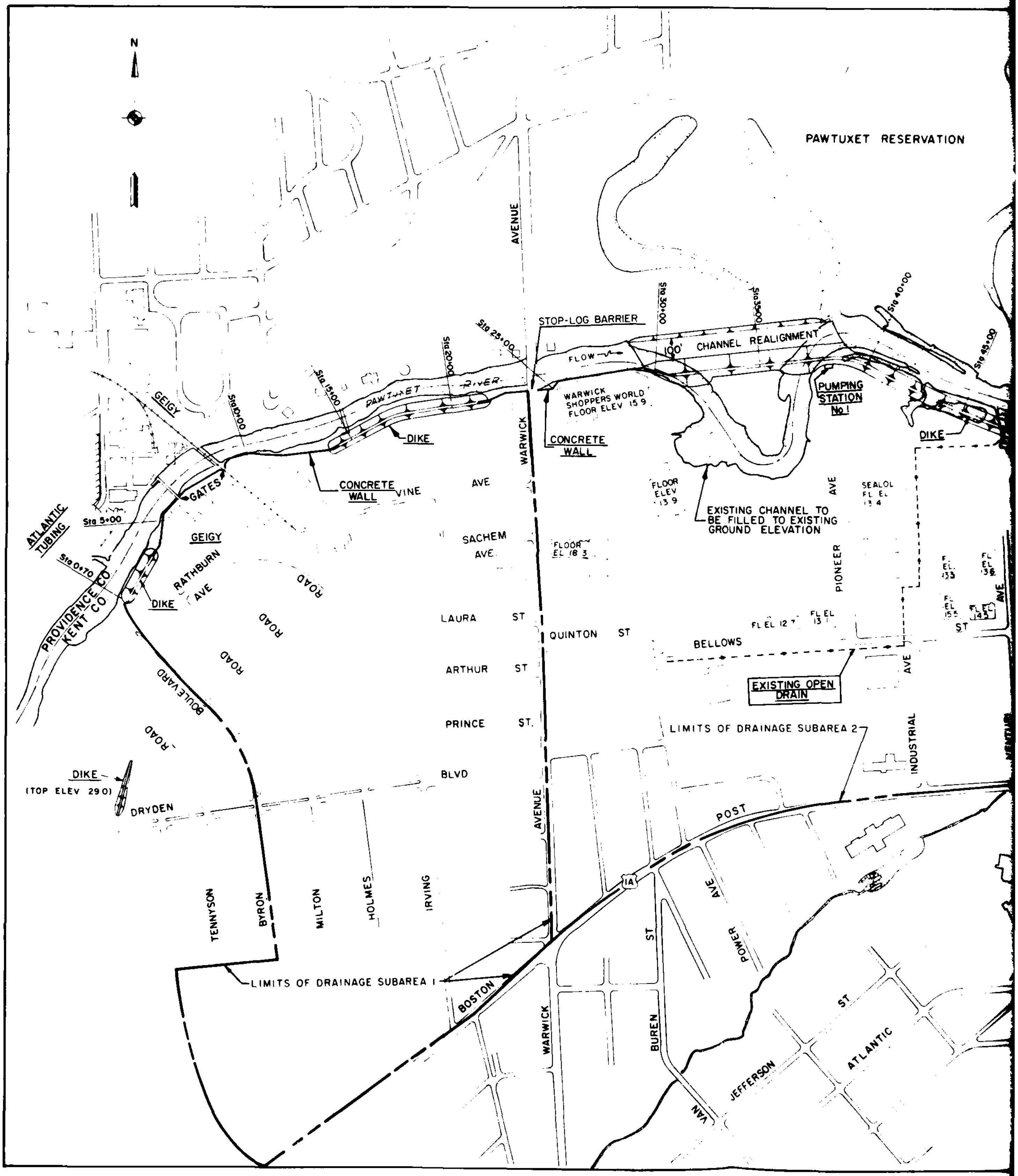
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
SOUTH BRANCH
RIVER PROFILE

PAWTUXET RIVER — RHODE ISLAND

SCALE: AS SHOWN — SPEC. NO. — DRAWING NUMBER — SHEET

PLATE 5



N
PAWTUXET RESERVATION
PAWTUXET RIVER
FLOW
STOP-LOG BARRIER
Sta 5+00
Sta 0+70
Sta 10+00
Sta 15+00
Sta 20+00
Sta 25+00
Sta 30+00
Sta 35+00
Sta 40+00
Sta 45+00
100' CHANNEL REALIGNMENT
PUMPING STATION No 1
WARWICK SHOPPERS WORLD FLOOR ELEV 15.9
CONCRETE WALL
CONCRETE WALL
DIKE
DIKE
DIKE
DIKE
(TOP ELEV 29.0)
GATES
GEIGY
GEIGY
ATLANTIC TUBING
PROVIDENCE CO
KENT CO
EXISTING CHANNEL TO BE FILLED TO EXISTING GROUND ELEVATION
FLOOR ELEV 13.9
FLOOR EL 18.3
SEALOL FL EL 13.4
FL EL 12.7
FL EL 13.1
EXISTING OPEN DRAIN
LIMITS OF DRAINAGE SUBAREA 2
LIMITS OF DRAINAGE SUBAREA 1
WARWICK AVENUE
VINE AVE
SACHEM AVE
RATHBURN AVE
LAURA ST
QUINTON ST
ARTHUR ST
PRINCE ST.
BELLOWS
PIONEER AVE
INDUSTRIAL AVE
BOULEVARD
ROAD
DRYDEN BLVD
TENNYSON
BYRON
MILTON
HOLMES
IRVING
POST ROAD
1A
BOSTON
POWER AVE
BUREN ST
VAN
JEFFERSON
ATLANTIC ST

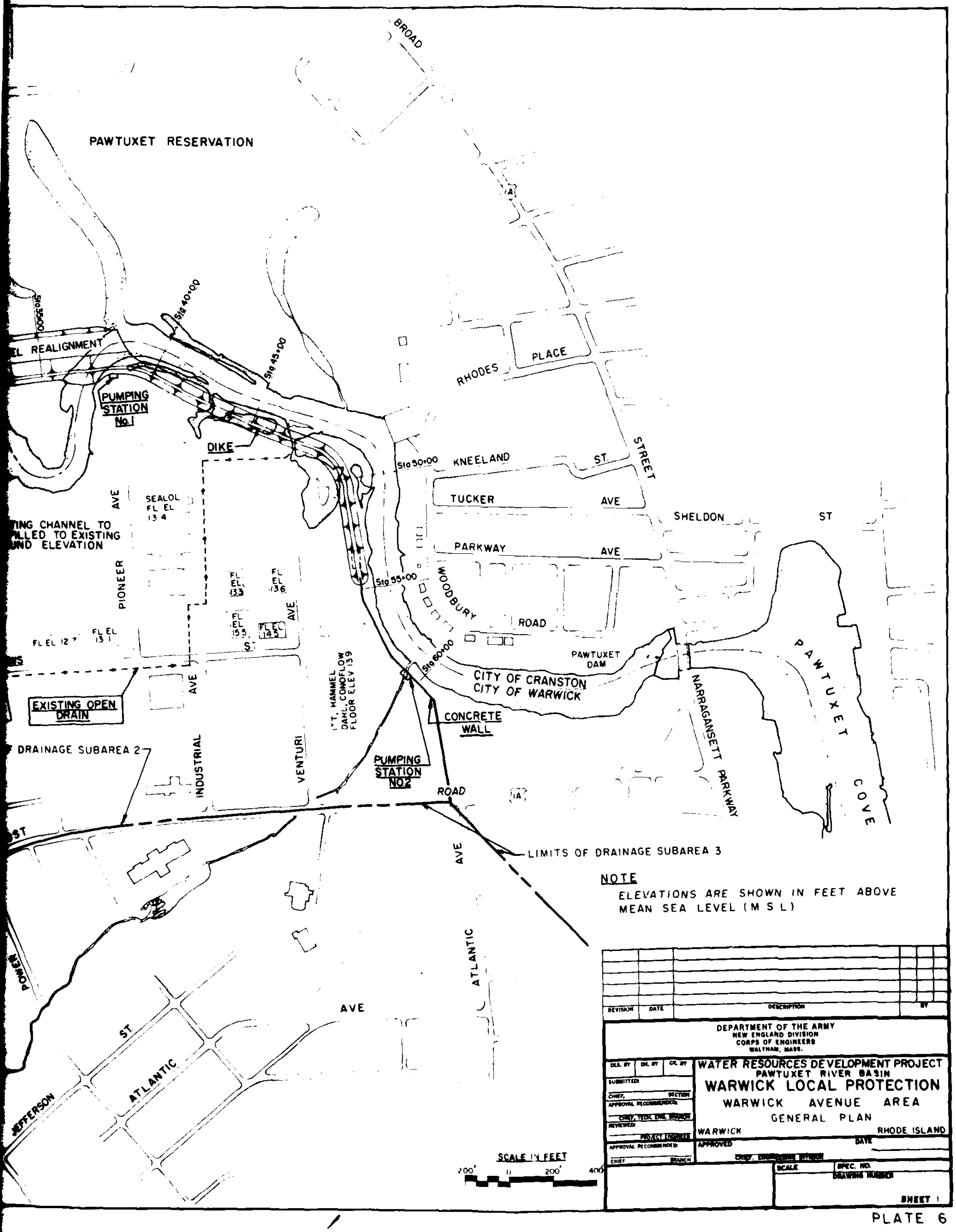
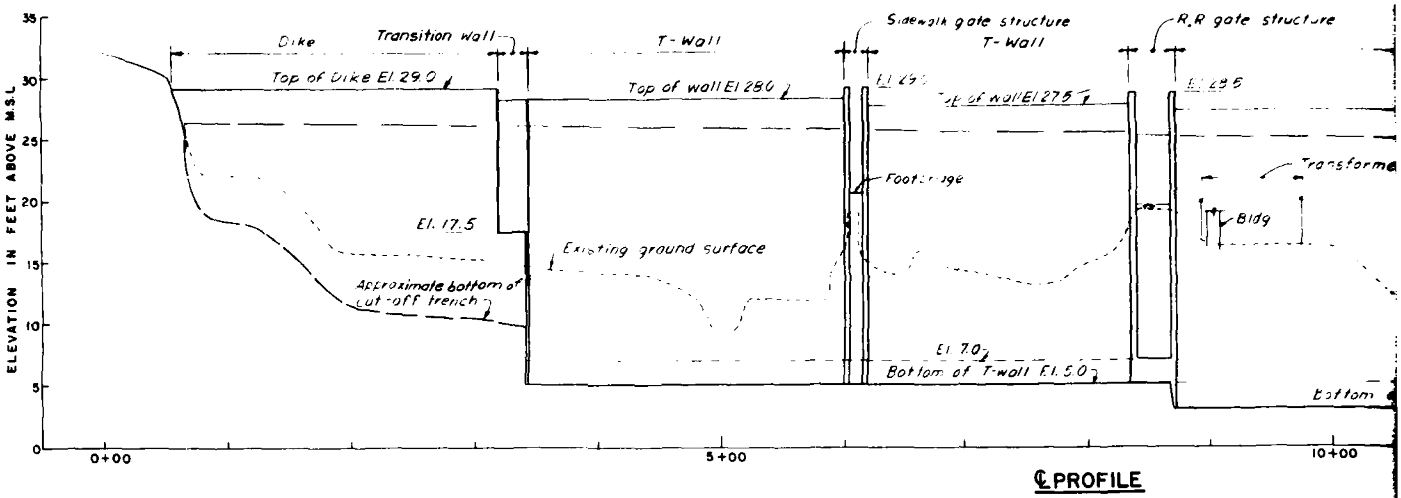
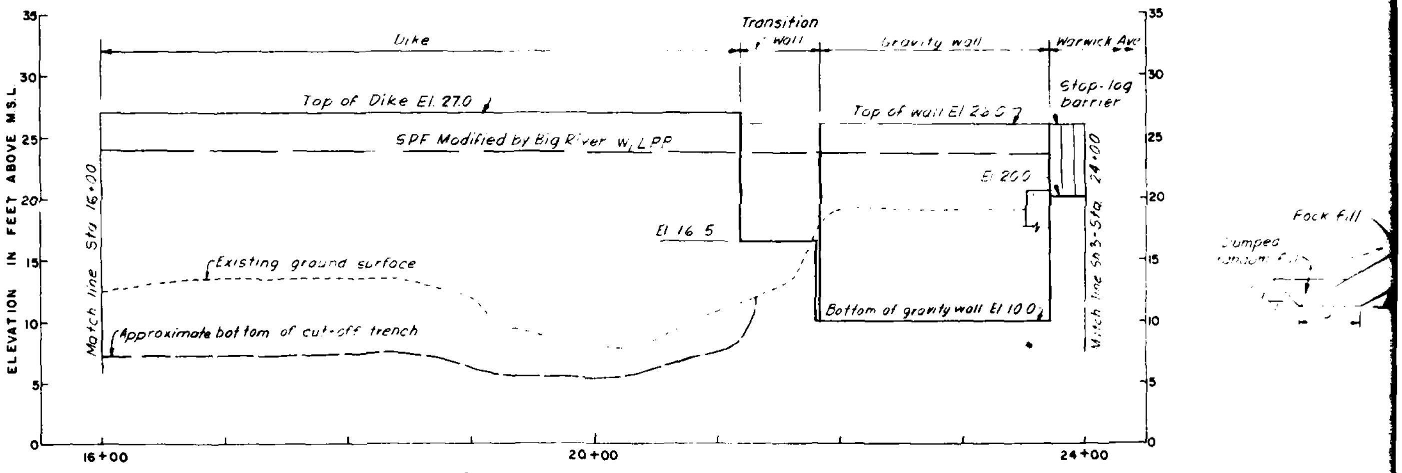

PAWTUXET RESERVATION
BROAD
Sta 35+00
Sta 40+00
Sta 45+00
Sta 50+00
Sta 55+00
Sta 60+00
EL REALIGNMENT
PUMPING STATION No.1
DIKE
RHODES PLACE
KNEELAND ST
STREET
TUCKER AVE
SHELDON ST
PARKWAY AVE
WOODBURY ROAD
SEALOL FL EL 13.4
ING CHANNEL TO
LLED TO EXISTING
ND ELEVATION
PIONEER
AVE
FL EL 13.3
FL EL 13.6
FL EL 15.5
FL EL 14.5
FL EL 12.7
FL EL 13.1
ST
PAWTUXET DAM
CITY OF CRANSTON
CITY OF WARWICK
CONCRETE WALL
PAWTUXET COVE
NARRAGANSETT PARKWAY
EXISTING OPEN DRAIN
DRAINAGE SUBAREA 2
INDUSTRIAL
VENTURI
PUMPING STATION NO.2
ROAD
LIMITS OF DRAINAGE SUBAREA 3
NOTE
ELEVATIONS ARE SHOWN IN FEET ABOVE MEAN SEA LEVEL (M S L)
ATLANTIC
AVE
ST
ATLANTIC
JEFFERSON
POWER
SCALE IN FEET
200' 0 200' 400'
REVISION
DATE
DESCRIPTION
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
GENERAL PLAN
WARWICK
RHODE ISLAND
SUBMITTED
APPROVAL RECOMMENDED
REVIEWED
APPROVED
DATE
SCALE
SPEC. NO.
DRAWING NUMBER
SHEET 1

PLATE 6



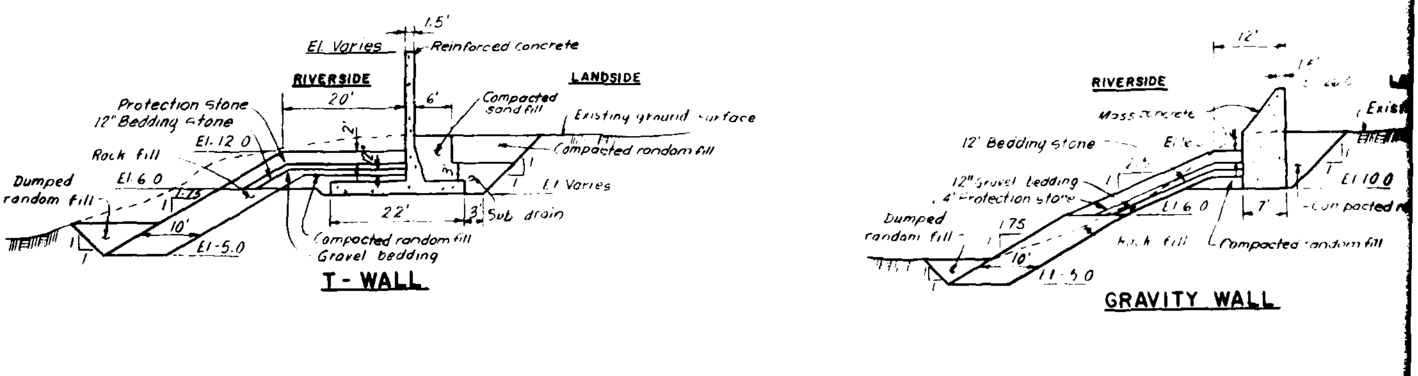
℄ PROFILE

SCALE: HOR 1" = 50' VERT 1" = 5'



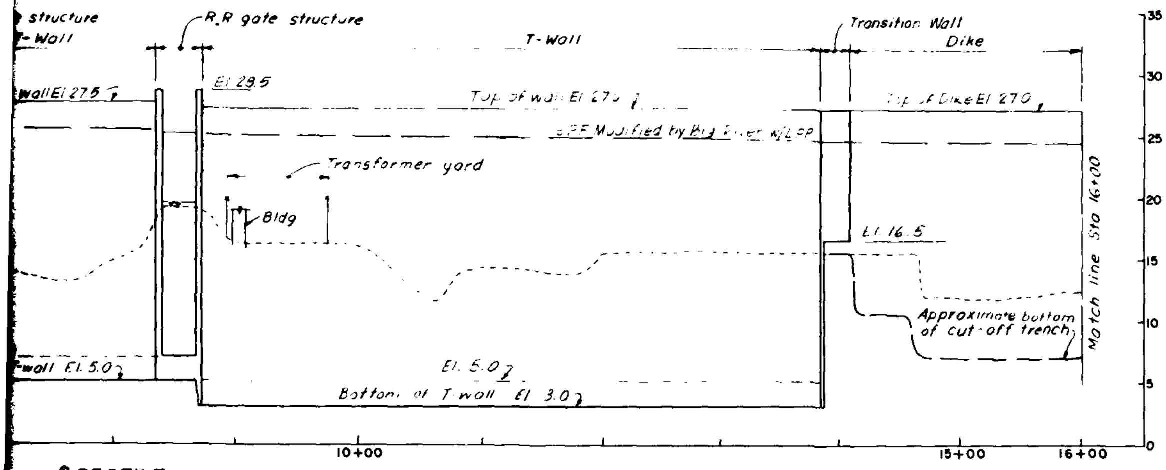
℄ PROFILE (CONT.)

SCALE: HOR 1" = 50' VERT 1" = 5'



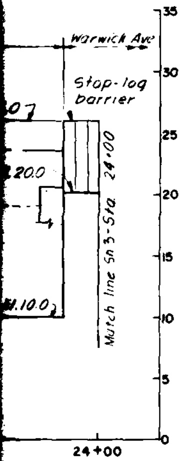
TYPICAL SECTIONS

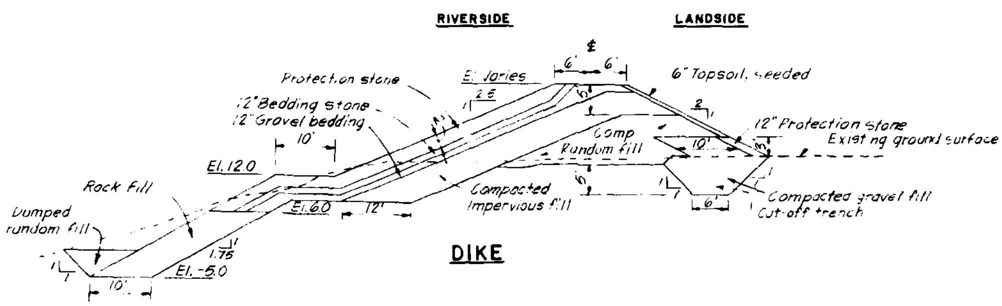
SCALE 1" = 10'



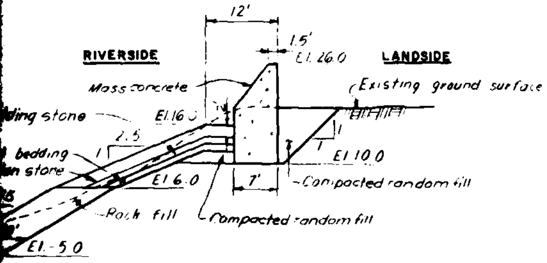
℄ PROFILE

SCALE: HOR 1" = 50'
VERT 1" = 5'





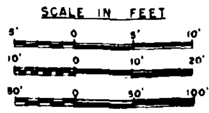
DIKE



GRAVITY WALL

TYPICAL SECTIONS

SCALE 1" = 10'



REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

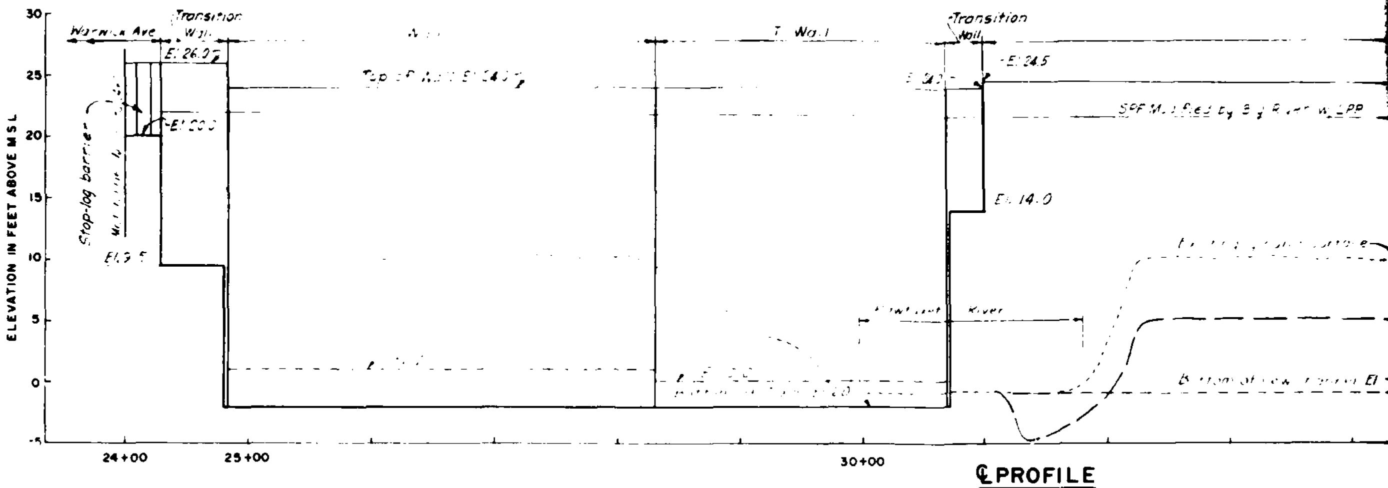
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
PROFILE AND TYPICAL SECTIONS NO 1
WARWICK RHODE ISLAND

APPROVED DATE

SCALE | SPEC. NO. | DRAWING NUMBER

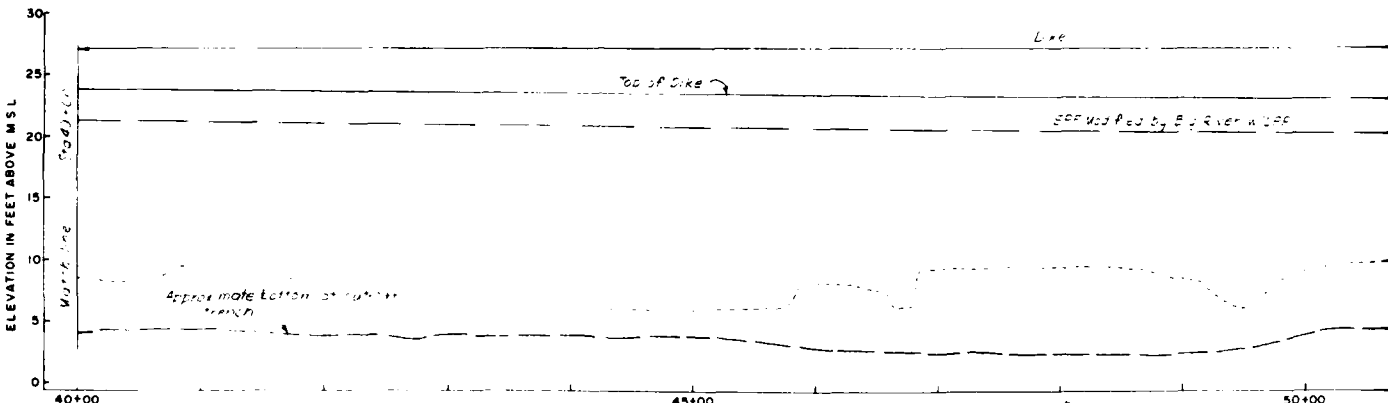
SHEET 2

PLATE 7



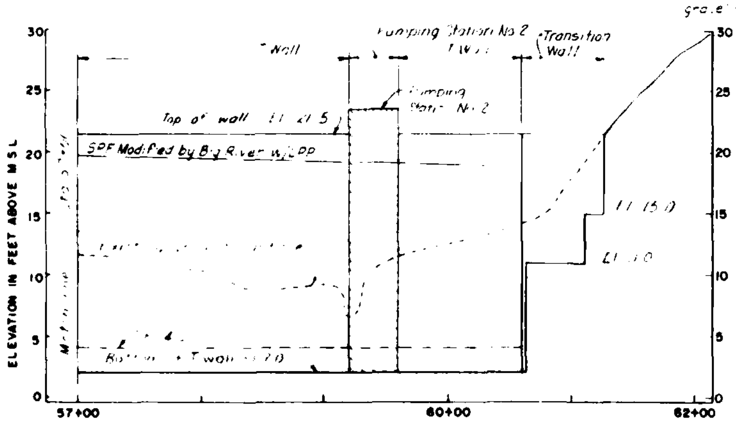
℄ PROFILE

SCALE HOR 1" = 50' VERT 1" = 5'



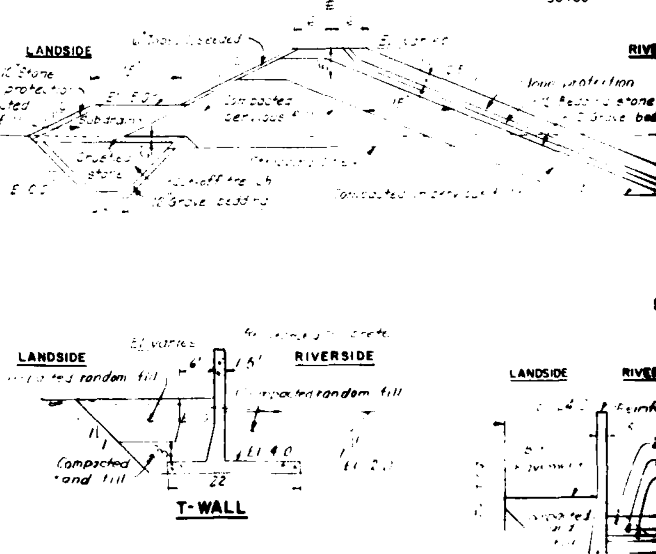
℄ PROFILE (CONT)

SCALE HOR 1" = 50' VERT 1" = 5'



℄ PROFILE (CONT)

SCALE HOR 1"=50' VERT 1"=5'

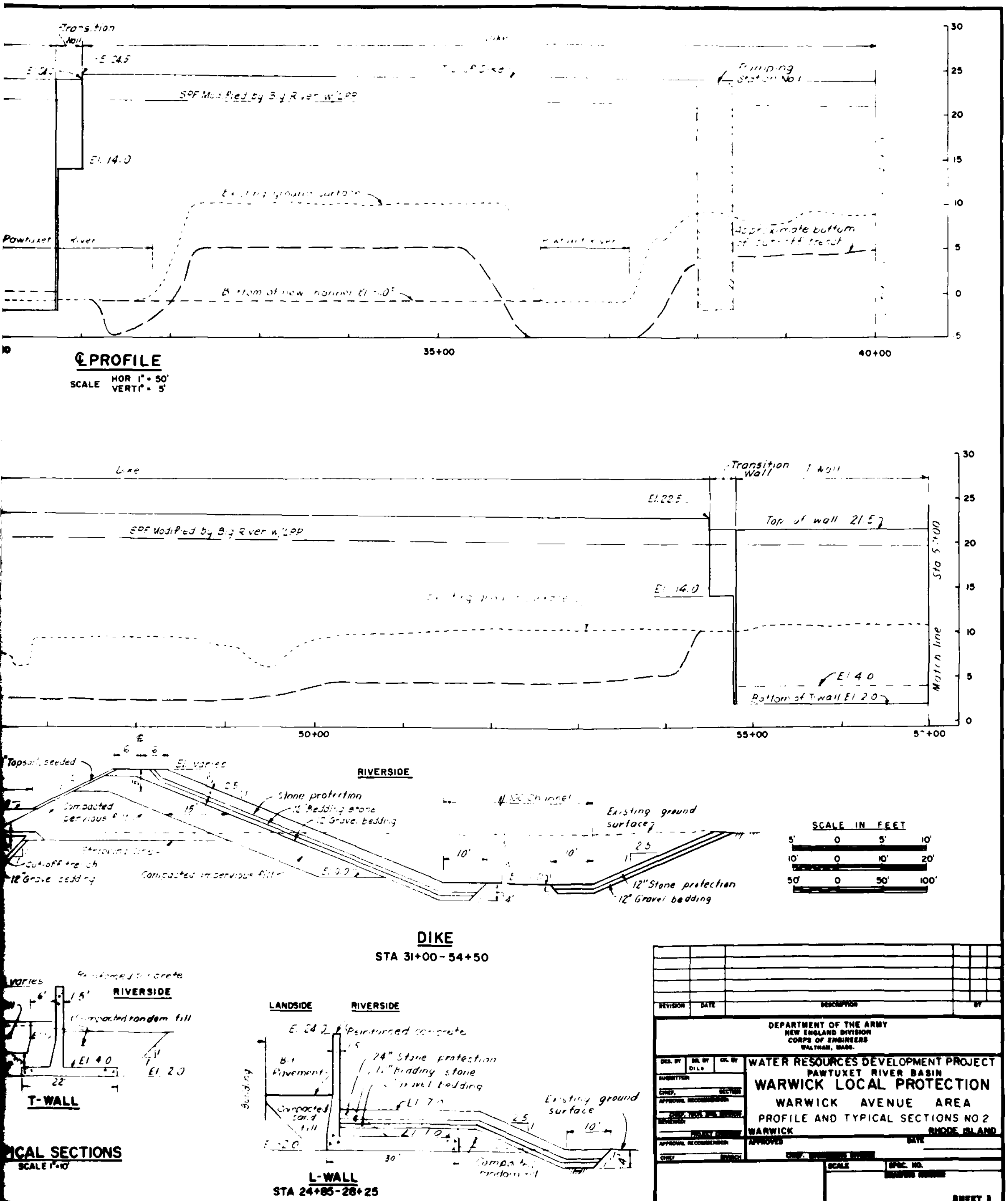


TYPICAL SECTIONS

SCALE 1"=10'

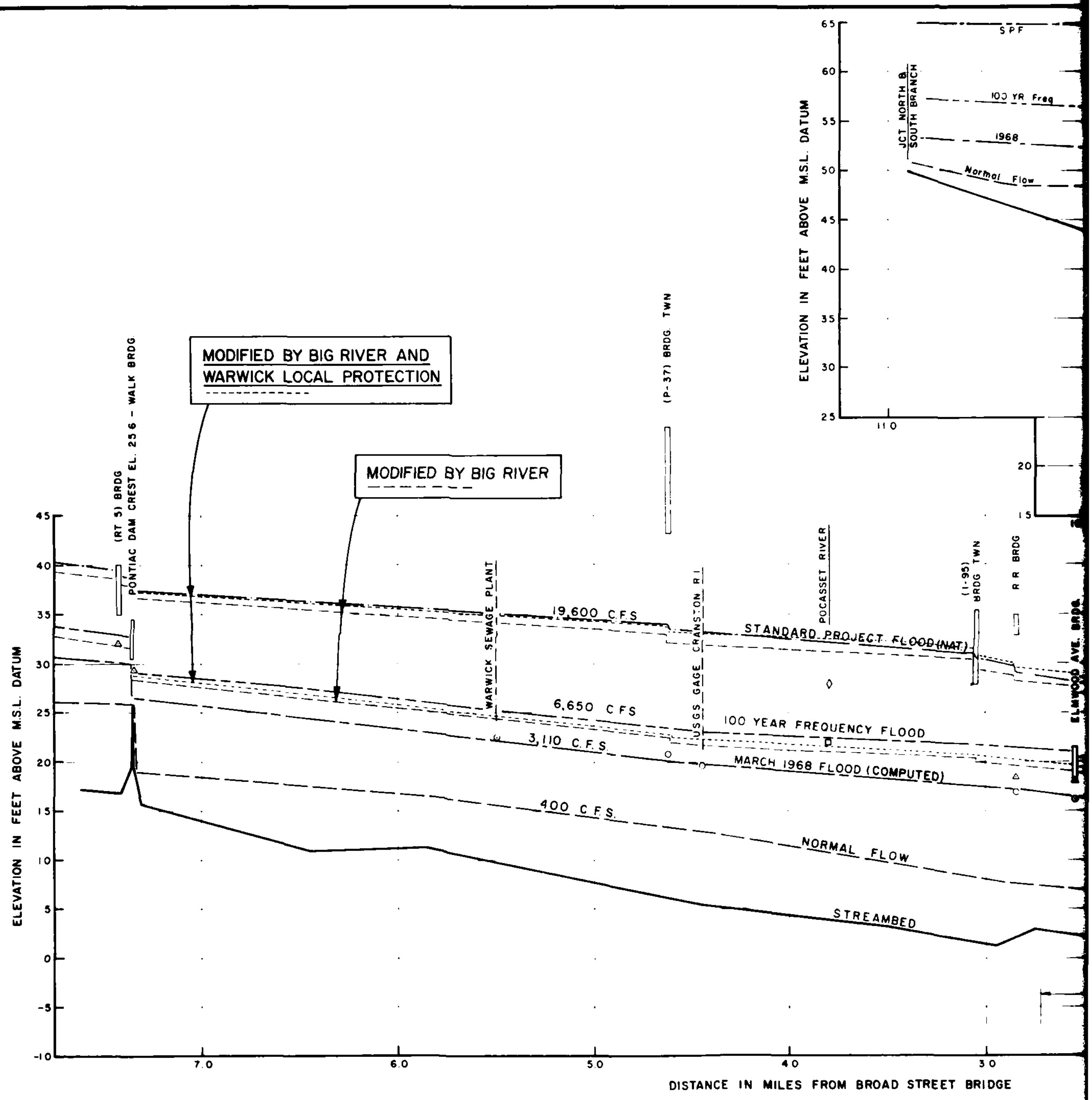
L-WALL

STA 24+65-28+2



Transition Wall
Dike
Pumping Station No 1
SPF Modified by Big River w/LPP
El 14.0
Existing ground surface
Pawtuxet River
Approximate bottom of cut-off trench
Bottom of new channel El -1.0
35+00
40+00
℄ PROFILE
SCALE HOR 1" = 50' VERT 1" = 5'
Dike
Transition Wall
T Wall
El 22.5
Top of wall 21.5
SPF Modified by Big River w/LPP
El 14.0
Sta 57+00
Match line
El 4.0
Bottom of T-wall El 2.0
50+00
55+00
57+00
Topsoil, seeded
El varies
RIVERSIDE
Stone protection
12" Bedding stone
12" Gravel bedding
Compacted pervious fill
Cut-off trench
12" Gravel bedding
Compacted impervious fill
Existing ground surface
12" Stone protection
12" Gravel bedding
SCALE IN FEET
DIKE
STA 31+00-54+50
Reinforced concrete
RIVERSIDE
Compacted random fill
El 4.0
El 2.0
22'
T-WALL
LANDSIDE
RIVERSIDE
Reinforced concrete
Bit Pavement
Building
24" Stone protection
12" Bedding stone
Gravel bedding
Compacted sand fill
Existing ground surface
30'
Compacted random fill
L-WALL
STA 24+85-28+25
TYPICAL SECTIONS
SCALE 1"=10'
REVISION
DATE
DESCRIPTION
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
WARWICK AVENUE AREA
PROFILE AND TYPICAL SECTIONS NO 2
WARWICK
RHODE ISLAND
APPROVED
DATE
SCALE
SPEC. NO.
SHEET 3

PLATE 8

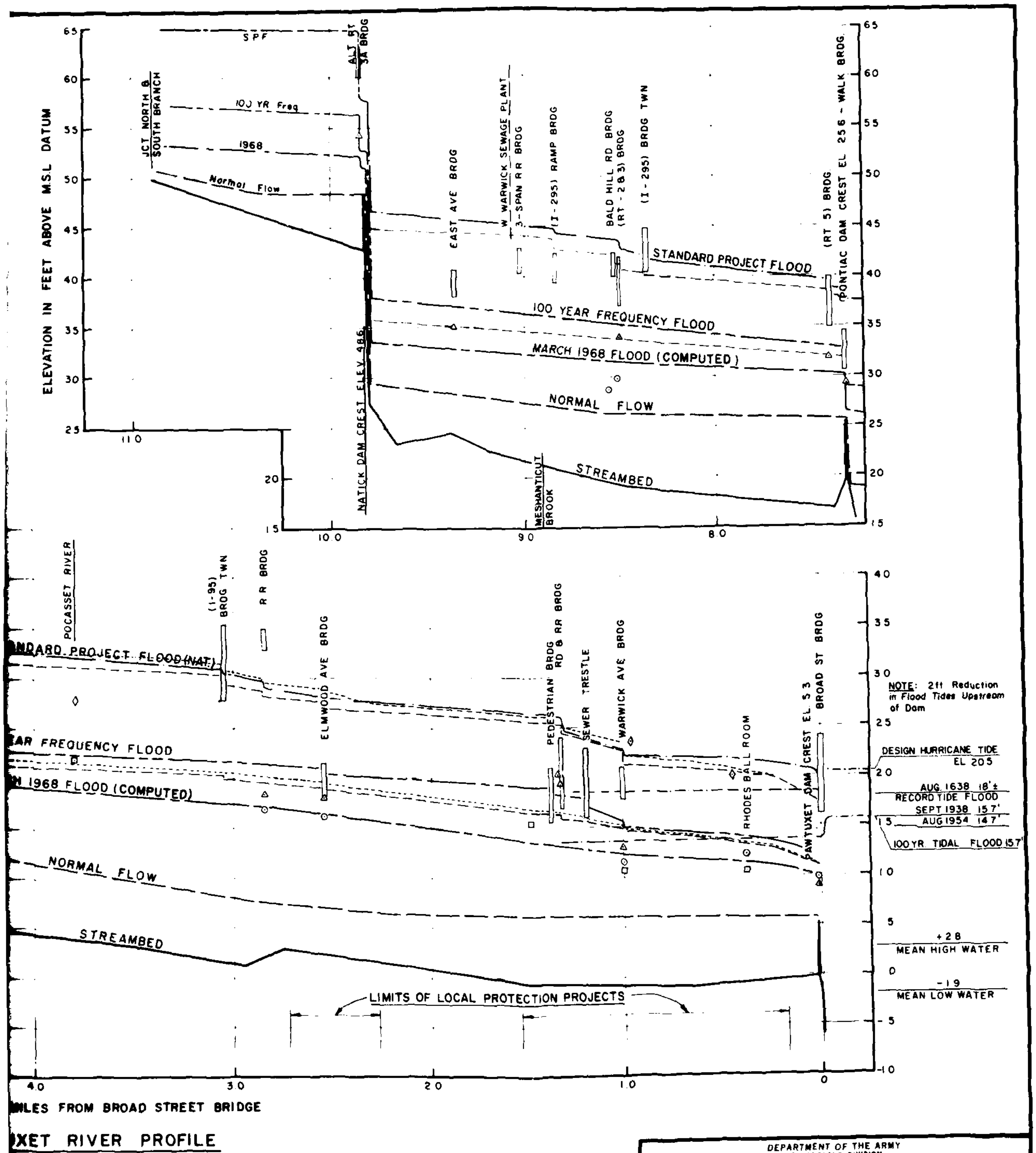


PAWTUXET RIVER PROFILE

LEGEND:

- △ INDICATES H.W.M. JULY 1938
- ⊙ INDICATES H.W.M. MARCH 1968
- ⊡ INDICATES H.W.M. MARCH 1936
- ◊ INDICATES H.W.M. FEB. 1886

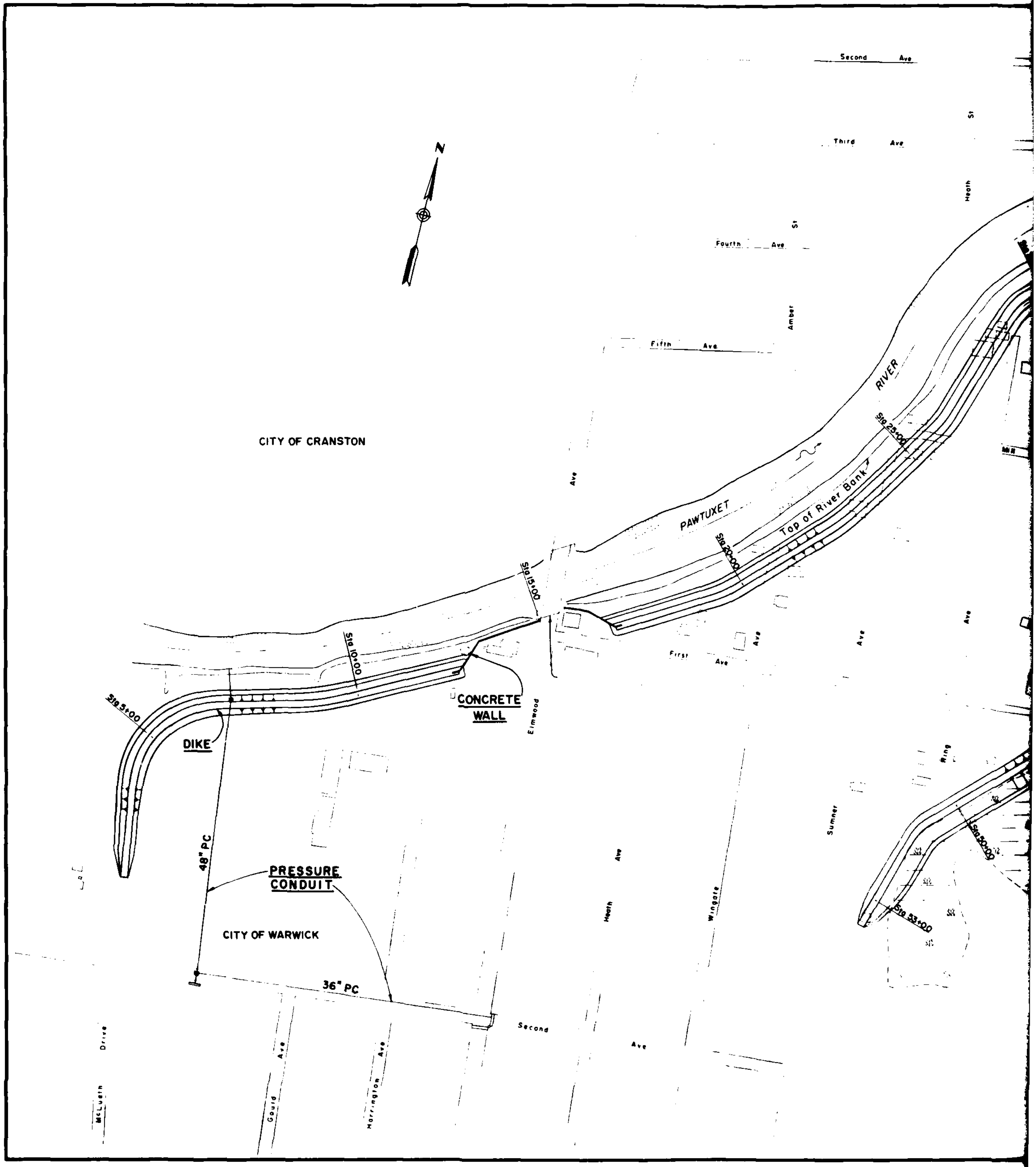
U. S ARMY



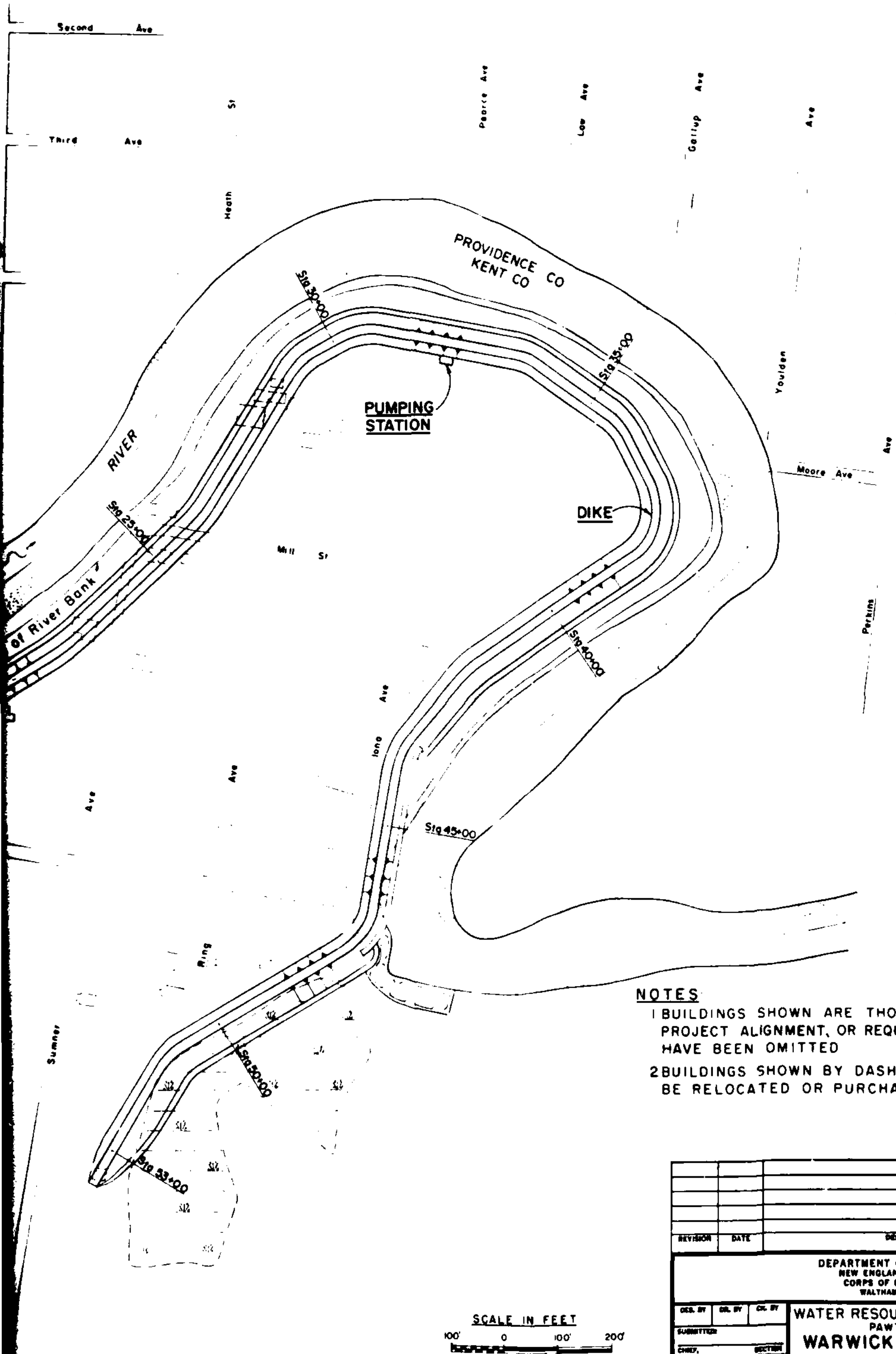
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
MAIN STEM FLOOD PROFILES
WITH EFFECTS OF BIG RIVER & L.P.P
PAWTUXET RIVER — RHODE ISLAND

PLATE 9



N
CITY OF CRANSTON
PAWTUXET
RIVER
Top of River Bank
Sta 5+00
Sta 10+00
Sta 15+00
Sta 20+00
Sta 25+00
Sta 50+00
Sta 53+00
CONCRETE WALL
DIKE
PRESSURE CONDUIT
48" PC
36" PC
CITY OF WARWICK
Second Ave
Third Ave
Fourth Ave
Fifth Ave
First Ave
Amber St
Heath St
Elmwood Ave
Heath Ave
Wingate Ave
Sumner Ave
Ring
McLuein Drive
Gould Ave
Harrington Ave



NOTES

1 BUILDINGS SHOWN ARE THOSE EITHER INFLUENCING PROJECT ALIGNMENT, OR REQUIRING RELOCATION, OTHERS HAVE BEEN OMITTED

2 BUILDINGS SHOWN BY DASH LINES WOULD NEED TO BE RELOCATED OR PURCHASED IN FEE

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
WARWICK LOCAL PROTECTION
ELMWOOD AVENUE AREA
GENERAL PLAN

NORWOOD RHODE ISLAND

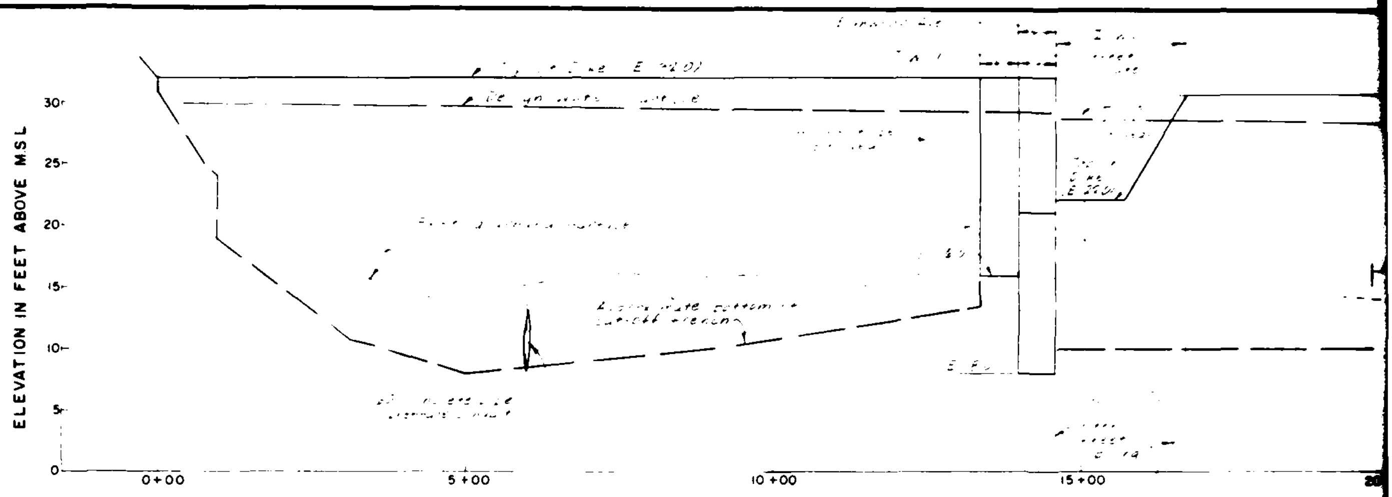
APPROVED DATE

SCALE SPEC. NO.

DRAWING NUMBER

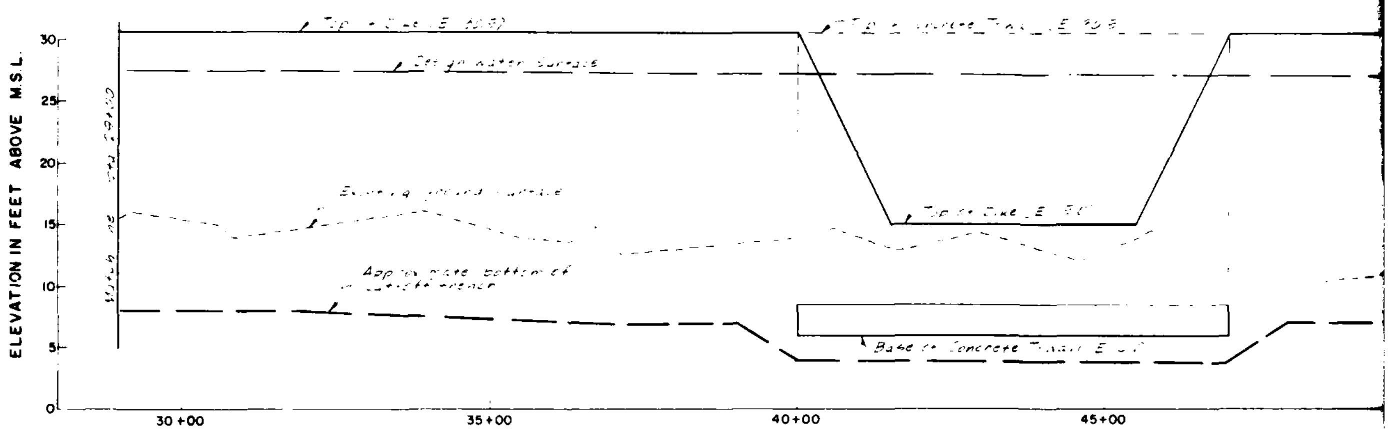
SHEET

PLATE 10



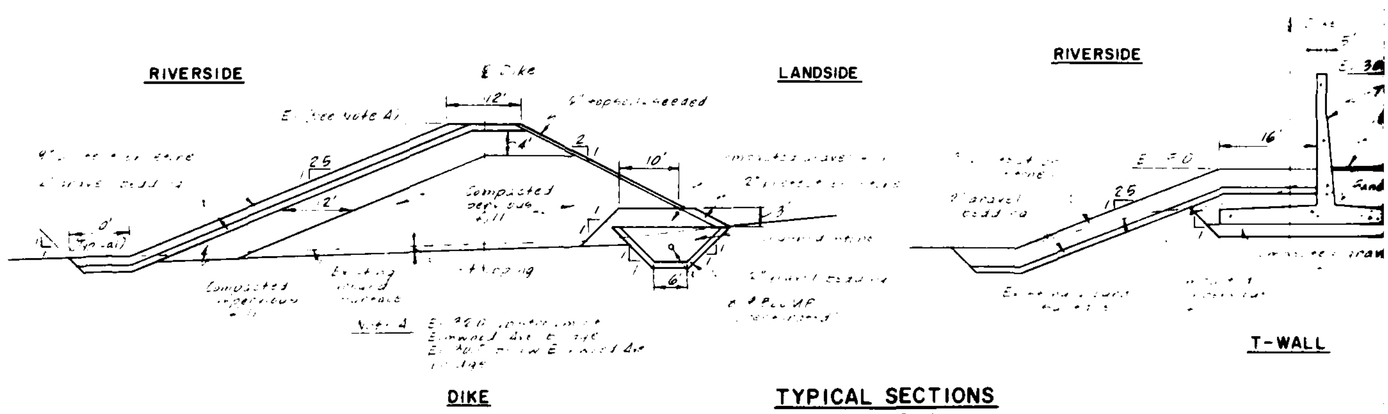
℄ PROFILE

SCALE HOR 1" = 100' VERT 1" = 5'



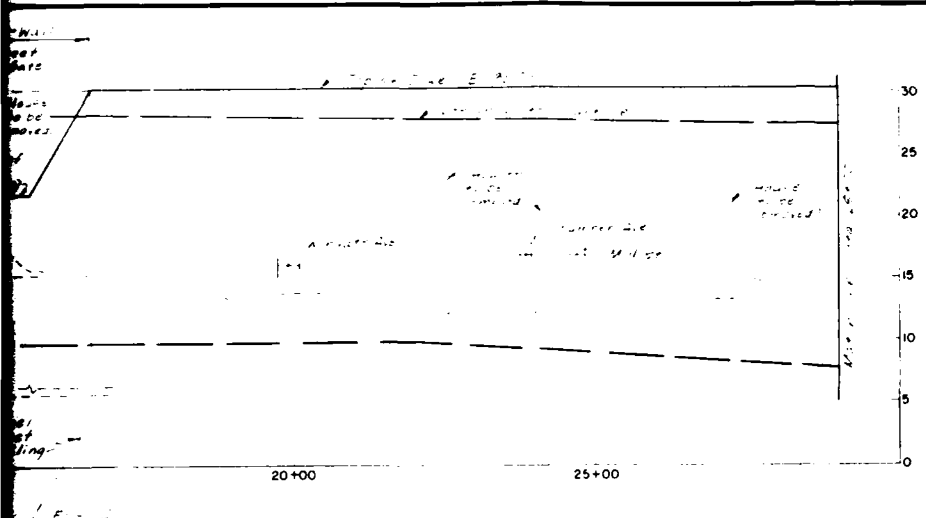
℄ PROFILE (CONT.)

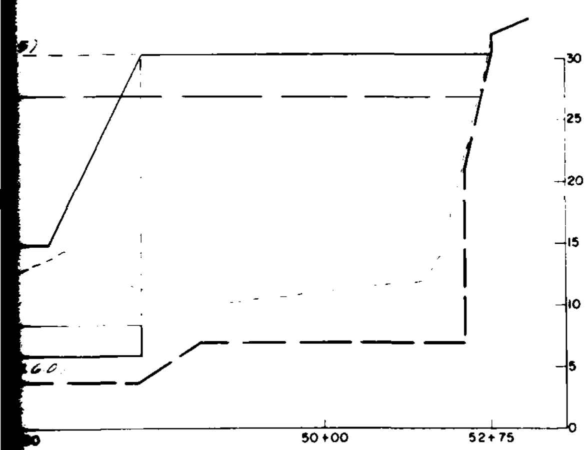
SCALE: HOR 1" = 100' VERT. 1" = 5'

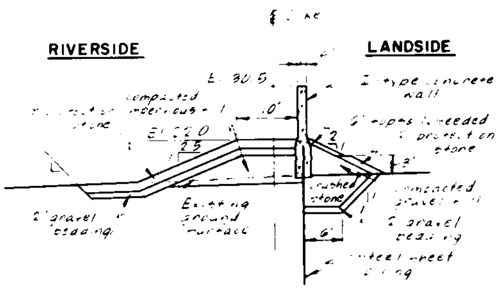


TYPICAL SECTIONS

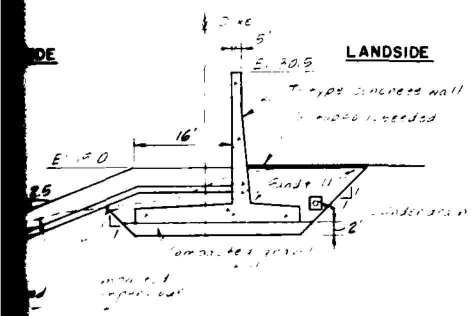
SCALE 1" = 10'



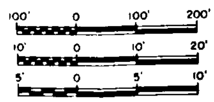




I-WALL



T-WALL



REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN

WARWICK LOCAL PROTECTION

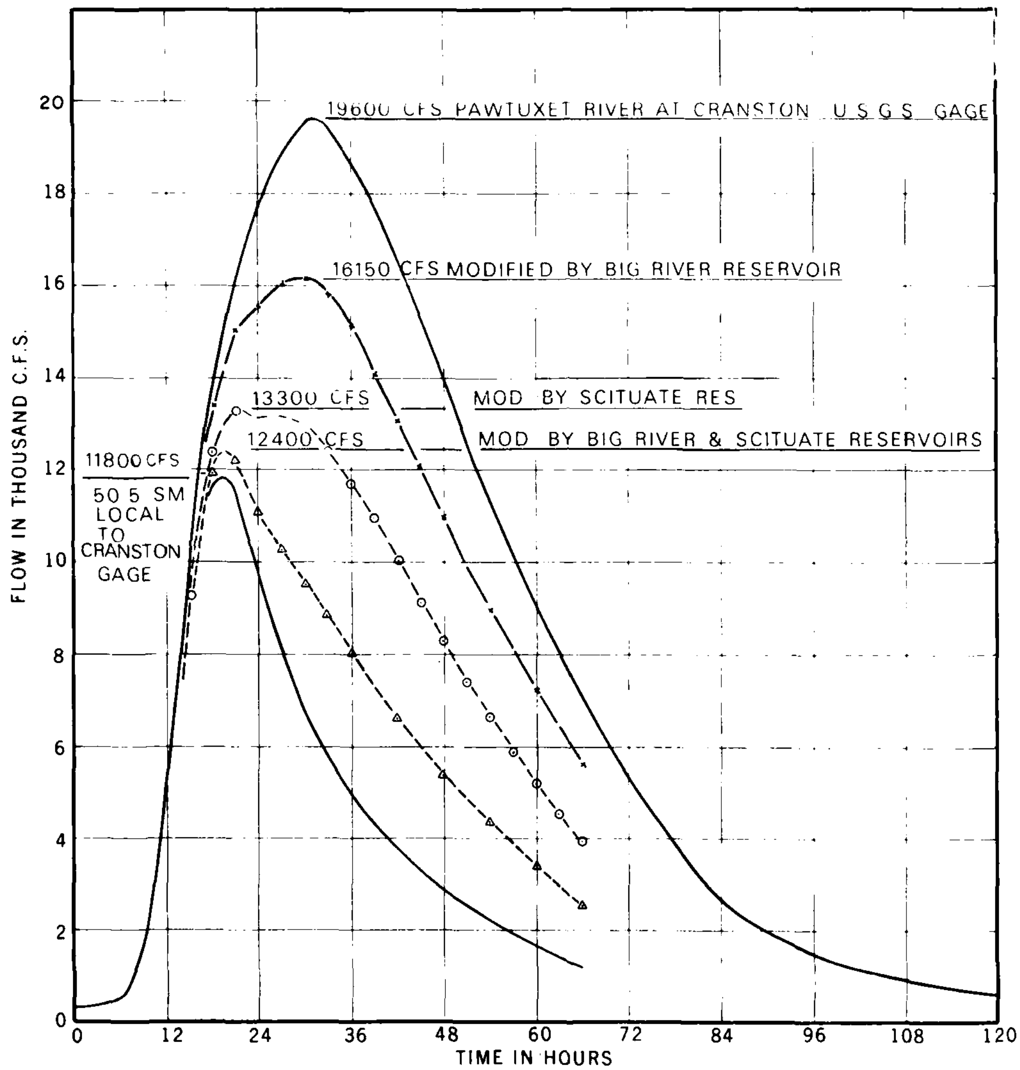
ELMWOOD AVENUE AREA

PROFILE AND TYPICAL SECTIONS

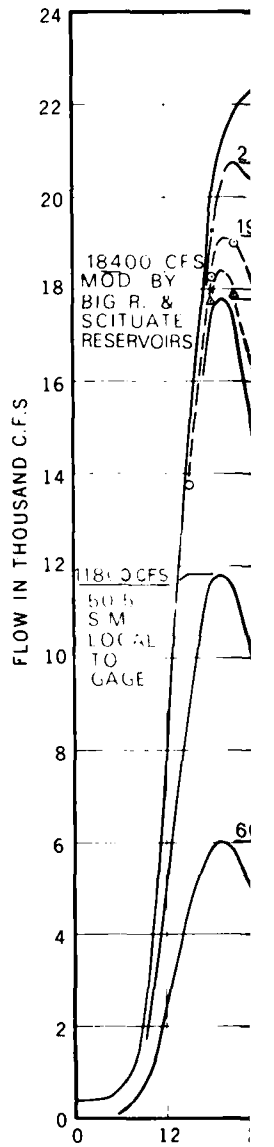
NORWOOD RHODE ISLAND

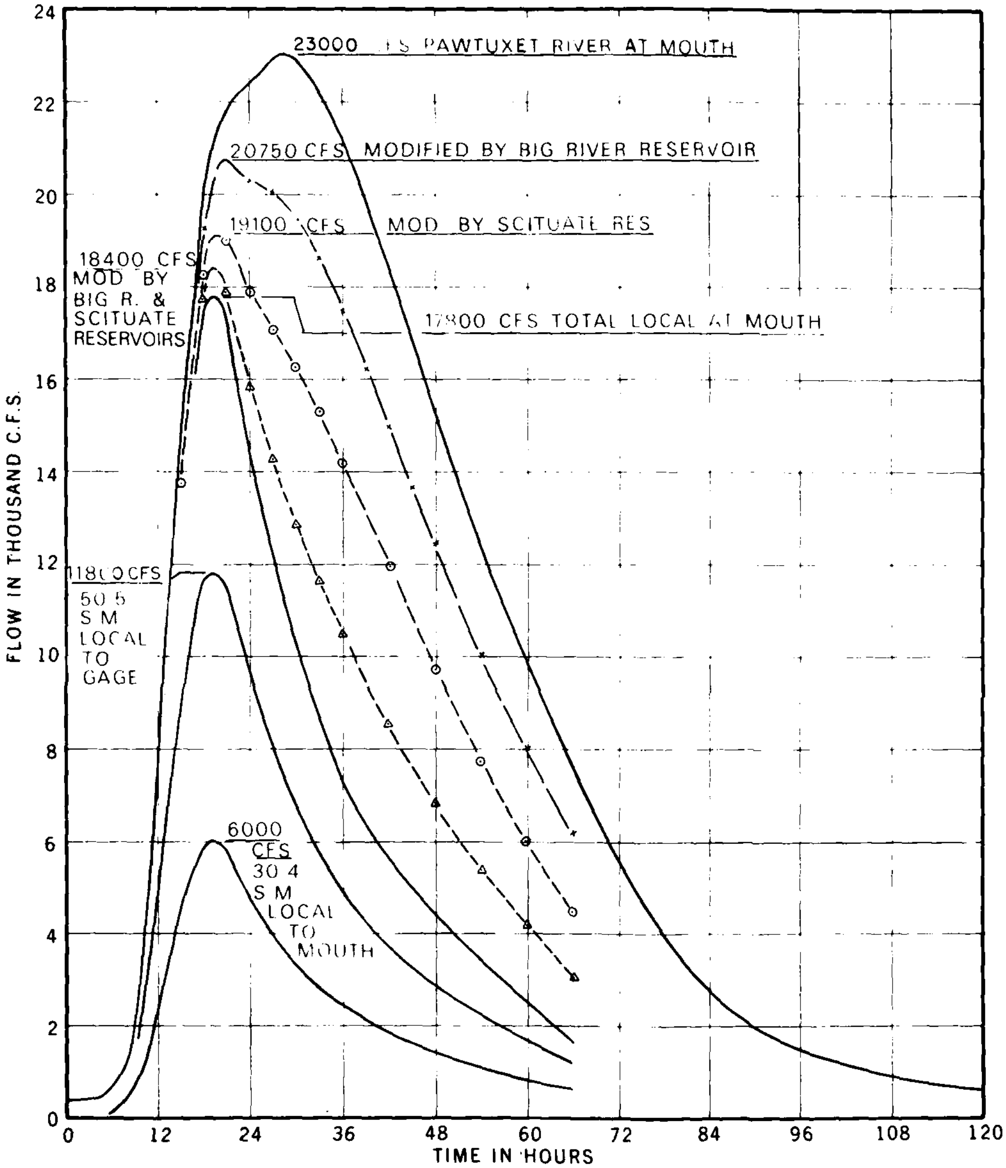
DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH
APPROVED DATE
CHIEF, ENGINEERING DIVISION
SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 11



S.P.F. AT CRANSTON U.S.G.S. GAGE
(200.0 Sq. Mi.)





S.P.F. AT MOUTH
(230.4 Sq. Mi.)

WATER RESOURCES DEVELOPMENT PROJECT

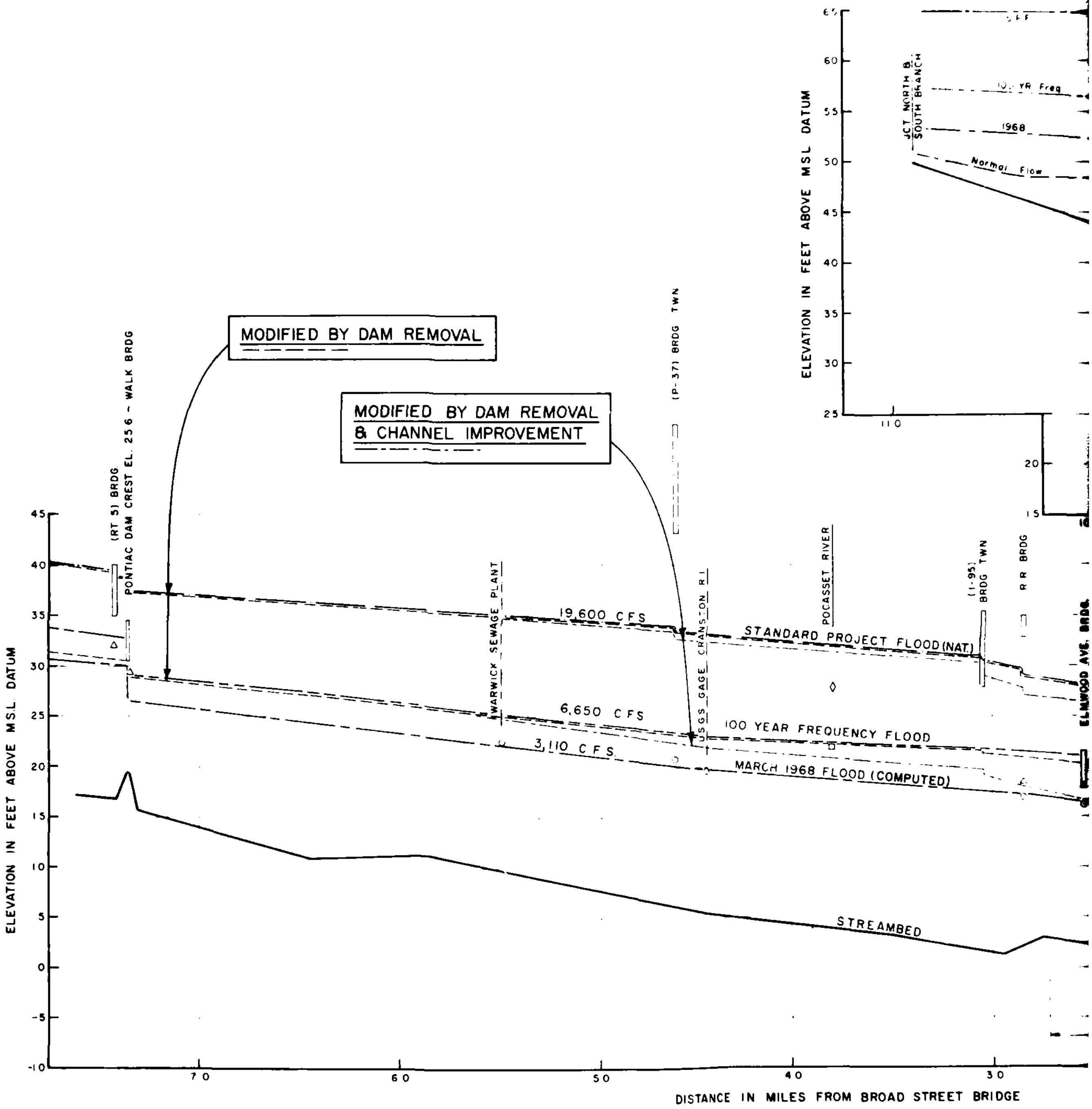
PAWTUXET RIVER BASIN

STANDARD PROJECT FLOOD COMPONENTS

PAWTUXET RIVER — RHODE ISLAND

PLATE 12

CORPS OF ENGINEERS



PAWTUXET RIVER PROFILE

LEGEND:

- △ INDICATES HWM JULY 1938
- ⊙ INDICATES HWM MARCH 1968
- ⊡ INDICATES HWM MARCH 1936
- ◊ INDICATES HWM FEB 1886

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CH
150
SE
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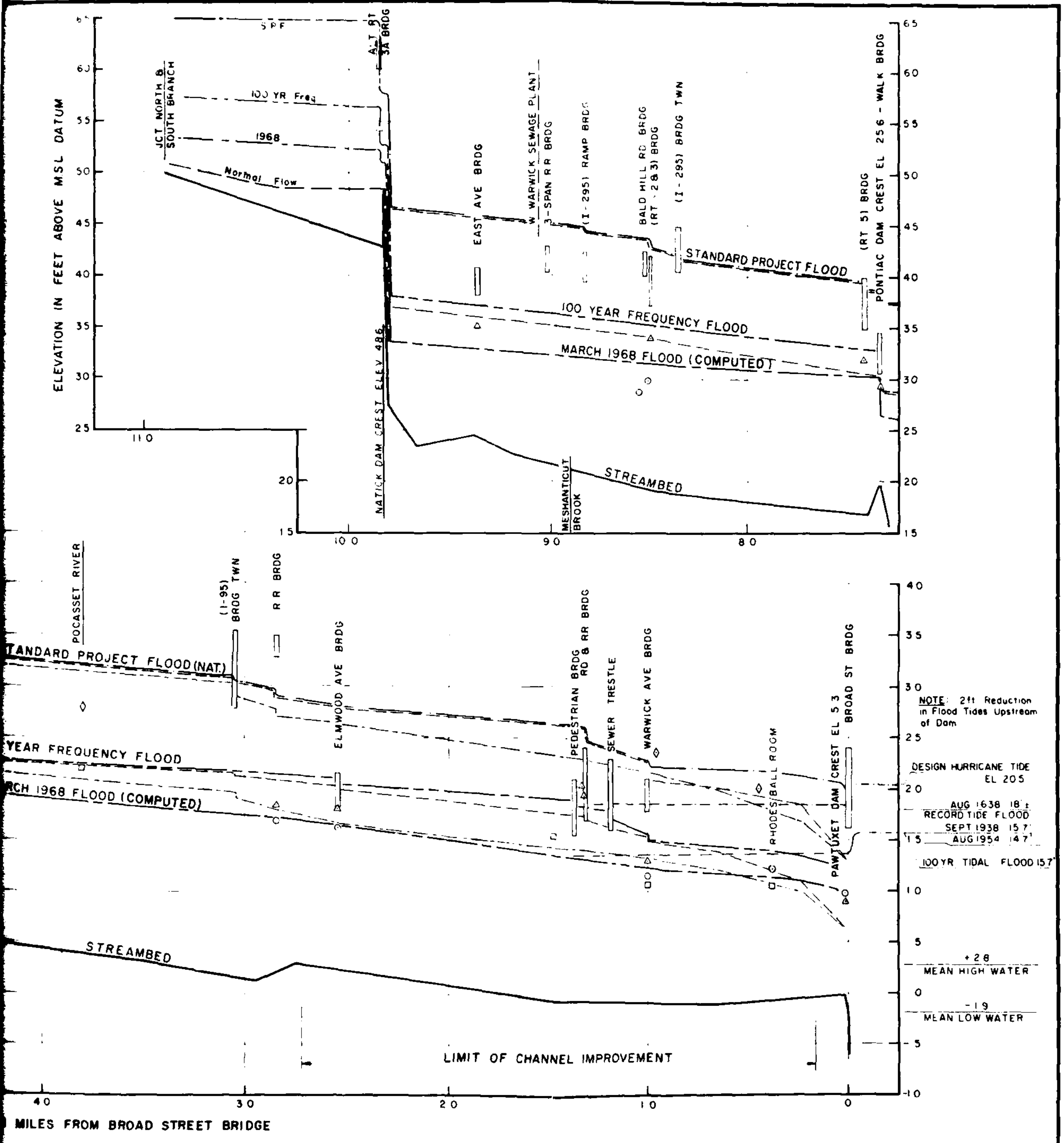
U. S ARMY



UXET RIVER PROFILE

NOTE
CHANNEL IMPROVEMENT CONSISTS OF 150 FOOT BOTTOM WIDTH TRAPAZOIDAL SECTION WITH 2 ON 1 SIDE SLOPES TO CONTAIN FLOOD

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
PAWTUXET RIVER BASIN
MAIN STEM FLOOD PROFILES-EFFECTS OF CHANNEL IMPROVEMENT & DAM REMOVAL
PAWTUXET RIVER RHODE ISLAND

DES. BY	DR. BY	CK. BY
SUBMITTED:		
CHIEF, SECTION		
APPROVAL RECOMMENDED:		
CHIEF, TECH. ENG. BRANCH		
REVIEWED:		
PROJECT ENGINEER		
APPROVAL RECOMMENDED:		
CHIEF BRANCH		

APPROVED DATE
CHIEF, ENGINEERING DIVISION
SCALE SPEC. NO
DRAWING NUMBER
SHEET

PLATE 13

TABLE OF CONTENTS

TABLES

PLATES

GEOTECHNICAL FEATURES

PAWTUXET RIVER BASIN

A. BASIN TOPOGRAPHY

The Pawtuxet River Basin is located entirely within central Rhode Island. The eastern two-thirds of the basin lies within the Seaboard Lowland section of the New England Physiographic Province; the western one-third of the basin is in the New England Upland section. The basin has irregular topography consisting of relatively low to moderate size hills in the west and gradually decreasing relief in the east. The maximum elevation is approximately 720 feet above sea level at Chopmist Hill in Scituate.

The river valley extends westerly from Warwick to the extensive Scituate Reservoir in Scituate. The meandering Pawtuxet River and other smaller rivers and streams drain the irregular topography which contains some large swamps.

Artificial modifications of landforms by cuts and fills are minimal throughout the basin except in Cranston and Warwick. Most of the urbanization of the basin has taken place in the eastern section around the Pawtuxet River.

B. SURFICIAL GEOLOGY

Unconsolidated deposits having various characteristics and thickness mantle the bedrock surface throughout the basin. The greatest exposure of bedrock and the thinnest surface cover are evident on the sides and tops of hills in the western and northern section of the basin, encompassed by the towns of Coventry, Scituate and Gloucester. Deposits of sand and gravel on land were primarily derived from glacial action. Deposits of post-glacial origin are lesser in extent and occur as alluvium and swamp deposits near streams and in blocked drainage areas on hills. Swamps contain varying amounts of soft organic silt and peat.

The distribution of surficial deposits is shown on Plate G-1. The deposits described in the following paragraphs were the most practical categories that could be shown according to the scale of the map. Several other types of glacial deposits exist but are too small to be differentiated here. Some of the engineering qualities of the materials in these deposits are listed in Table G-1.

The principal types of deposits are as follows:

Ground Moraine (Till) - Ground moraine or glacial till consists of an unsorted mixture of rock particles ranging from clay-size to boulders. It has the most extensive and widespread occurrence covering hills and lowlands. The deposits are often thin enough to reflect the underlying topography.

Thick masses of *ground moraine* sometimes are formed into hills. The rock particles in the till are mostly from local bedrock. Ground moraine may be buried by other surficial deposits.

Outwash Plains - Outwash plains are flat-topped broad accumulations deposited in open areas by glacial meltwater. They consist of sands with some interbedded gravel. Plains that have coalesced may cover wide areas; others may form limited deposits in narrow valleys. The surfaces of plains can be relatively featureless or slightly irregular with depressions.

Kame Terraces and Valley Train Deposits - Kame terraces are benched deposits of sand and gravel left against valley slopes by glacial streams. Valley train deposits are sands and gravels in valleys and extending across them. Kame terraces and valley train deposits sometimes merge from one into the other. They have been combined as a single map unit.

Kame Plains - Kame plains are localized flat-surfaced deposits of mostly sand with some gravels. They were formed by glacial streams in areas confined by the glacier. The bordering slopes of the deposits may be either steep or flat. The sands and gravels are usually sorted and stratified.

Kames - Kames are irregular hills usually of poorly sorted sand and gravel that were deposited in contact with the glacier. The deposits are often localized because of the confined conditions during their formations.

Sand and Gravel, Undifferentiated - Sands and gravels that were not mapped as any particular type of land form are left as undifferentiated deposits. The grain size, sorting, and stratification within these deposits vary according to the local conditions of deposition. The properties may be those of sands, gravels, and mixtures of sands and gravels.

Alluvium - Alluvium accumulates in river and stream channels. The deposits form banks and flood plains along rivers and streams. The materials are silt, sand, and gravel. Usually the deposits are well sorted. The nature of erosion and deposition by the rivers and streams in normal times and during floods determines the local sorting, thickness and distribution of the deposits.

Swamp Deposits - Swamp deposits mainly are silts, fine sands and muck. They are widely distributed. Most swamps are localized and limited in extent although a few extensive areas are found. The level of water in swamps will fluctuate seasonally with local stream and ground-water levels. The thickness of the swamp deposits is determined by local conditions.

Artificial Fill - Artificial fills are extensive enough for mapping in the Providence Quadrangle. Fill material is usually taken from local sources of till or sand and gravel. The kind of material used depends largely upon the purpose of the fill.

a. Planning Factors - The strongest geologic restraints placed on future plaining and development of the basin are the topographic conditions. Foundation conditions in glacial deposits are generally good within the basin area. Subsurface drainage within till areas is normally poor to fair, especially where the bedrock is near or at the ground surface. Landforms govern to a high degree the corridors available for transportation, utilities and future expansion of the existing communities, especially in the northern and western sections of the basin.

The eastern and southeastern sections, where most of the glaciofluvial deposits occur, is highly developed due to the relative ease that man can work with and modify these materials for his use. Low permeable soils in the hills and a frequent high ground-water level in the valleys make careful planning of solid and liquid waste disposal a necessity. Planning concepts should place strong emphasis on the highly variable topography and subsurface materials throughout the basin. Consideration to the areas of significant flood plains is an important factor.

b. Engineering Factors - Where designs are to be effective, careful consideration should be given to bearing capacity and surface and ground-water conditions within the soil mass. Generally, bearing capacities of the soils in the basin are good, except for the highly compressible organic soils in swamps. Control of surface water during and after construction is a necessity in areas of low permeability soils. To avoid ground-water problems in proposed projects, it is important that the ground-water level be monitored to aid in siting. Some engineering characteristics of the materials are shown in Table G-1.

c. Construction Factors - Generally, excavation in the till areas is moderately difficult to difficult due to the high density of the soil and presence of boulders. In addition, the bedrock is commonly near or at the ground surface which may necessitate expensive rock excavation. Glaciofluvial deposits of sand and gravel in the valleys are normally the most desirable types for modification in construction projects. (See Table G-1)

C. BEDROCK GEOLOGY

The bedrock of the basin includes metamorphic, igneous and sedimentary types. The distribution of formations and general localities of bedrock outcrops are shown on Plate G-2. A map of the detail geology of the Clayville Quadrangle in the northwest portion of the basin was not available for this compilation. Therefore, outcrops are not located in that area. Selected engineering characteristics of the formations are shown in Table G-2.

The most extensive formation is the Scituate Granite Gneiss which occupies almost the entire central portion of the basin. At the eastern margin of the formation there is a complex of igneous and metmorphic rock types that trends roughly north-south. Farther to the east the sedimentary rocks of the Rhode Island Formation begin. They are primarily sandstone, slate, conglomerate. and graywacke. North and northwest of the Scituate Granite Gneiss

are mainly gneisses and schists.

Faults are mapped at two locations. One is in the Cranston Quadrangle near the town of Cranston about 500 feet west of the margin of the Narragansett Basin. This small fault displaces Pondville Conglomerate and Esmond Granite. Another fault is at the north end of the Scituate Reservoir and occurs along the contact of the Bellingham Conglomerate and the Scituate Granite Gneiss. There is no information of displacements. Neither fault is considered active or major.

As indicated in Table G-2, engineering properties of rocks that are pertinent to foundations, excavations, slopes and construction materials vary with rock type. In general igneous and metamorphic rocks are hard, highly jointed weak to strongly foliated and range in compressive strength from medium to very high. Also, they show slight weathering and high durability. Sedimentary rocks generally are more deeply weathered and have low to medium compressive strengths.

a. <u>Planning Factors</u> - Due to their high strength values and durability, the igneous and metamorphic rock types are desirable for use as a construction material. However, they are normally difficult to excavate. Principal use of the rock is anticipated to be aggregates for construction purposes. Sedimentary rocks are often unsuitable for construction purposes or dimension stone. Future utilization of the bedrock resources in the basin may be anticipated to be in the igneous rock areas where foliation is minor. Principal use of the igneous rock is anticipated to be aggregates for the construction industry. Other planning factors related to bedrock can be evaluated by referring to Plate G-2 and Table G-2.

b. <u>Engineering Factors</u> - The igneous and metamorphic rocks in the basin allow design utilizing the high compressive strength, slight weathering and good to excellent durability characteristics. The foliation in metamorphic rocks requires care in design of cut slopes, especially in the micaceous schist types. The sedimentary rocks are usually less dense but normally provide adequate strength and durability for most design purposes. Conglomerate formations, although a minor occurrence in the basin, present irregular and somewhat difficult characteristics for excavation. (See Plate G-2 and Table G-2)

c. <u>Construction Factors</u> - Construction relating bedrock within the basin largely depends on the location of the bedrock surface. Activity on the sides and tops of hills may encounter rock that normally presents high excavation difficulty with good slope stability. Within the valleys and plains it is doubtful whether construction activity will encounter the relatively deep bedrock surface. The sedimentary rock formation surface is usually deeper than the igneous and metamorphic rock types and may not be encountered in most construction projects. Where these sedimentary rocks are encountered, they are somewhat easier to excavate, except for conglomerate, and all have

generally good slope stability characteristics. Further evaluation of the bedrock formations in relationship to their construction characteristics can be evaluated by reference to Plate G-2 and Table G-3.

D. SEISMIC ACTIVITY

The majority of the basin is in zone 1 of the Seismic Risk Map. Zone 1 is classified as having potential damage from earthquakes with corresponding maximum intensities of V and VI of the Modified Mercalli Scale. The northern most part of the basin borders on zone 2 which may undergo moderate damage (intensity VII of the M.M. Scale). Epicenters with corresponding intensities in the range of III to VI have been indicated for the Rhode Island area. The seismic potential of earthquakes with epicenters in Rhode Island as well as in the surrounding vicinity should be evaluated and appropriate factors applied to designs for construction.

SELECTED ENGINEERING CHARACTERISTICS OF SURFICIAL DEPOSITS

MATERIAL DESCRIPTION	THICKNESS OF DEPOSIT	EXCAVATION CHARACTERISTICS	BEARING CAPACITY (1)	AVERAGE NATURAL SLOPE (DEG)	CUT SLOPES MAXIMUM (DEG)	COMPRESSIBILITY AND EXPANSION	UNIT DRY WEIGHT (PCF)	EXCAVATION PERMEABILITY GAL/DAY/CY
AF - ARTIFICIAL FILL VARIABLE ACCORDING TO PURPOSE	VARIABLE	EASY TO DIFFICULT	POOR TO GOOD DEPENDING UPON NATURE OF MATERIAL	VARIES WITH MATERIAL TYPE	VARIES WITH MATERIAL TYPE	VARIES WITH LAND USE	VARIABLE	UNKNOWN
AL - ALLUVIUM SILT, SAND, AND SOMETIMES GRAVEL	VARIABLE. OFTEN FEW TENS OF FEET, OCCASIONALLY THICKER.	EASY	POOR TO FAIR (SANDY) VERY POOR TO POOR (SILT AND CLAY)		STABLE TO ANGLE OF REPOSE, REQUIRE SUPPORT BELOW WATER TABLE	NEGLIGIBLE	VARIABLE	50-1000
GM - GROUND MORAINE. UNSORTED MIXTURE OF CLAY, SILT, SAND, GRAVEL, BOULDERS. GENERALLY COMPACT, FIRM AND FRIABLE.	VARIABLE BUT GENERALLY LESS THAN 25 FT. THIN TO ABSENT ON HILL CRESTS. THICKER TO 50 FT OR MORE ON LOWER SLOPES. MAY FORM HILLS 150 FT OR MORE	EASY TO DIFFICULT VARIES WITH CHARACTERISTICS OF DEPOSIT	GENERALLY GOOD	25°	0-15 FT=90° 15-40 FT=28° 40 FT OR MORE FROM ANALYSIS	NEGLIGIBLE	100-135	1-35
K - KAMES COARSE GRAVEL, OR SAND AND GRAVEL. POORLY SORTED TO WELL SORTED LOCALLY.	VARIABLE TO SEVERAL TENS OF FEET	EASY	FAIR (SAND) TO GOOD (GRAVEL)	5°	STABLE TO ANGLE OF REPOSE, REQUIRE SUPPORT BELOW WATER TABLE.	NEGLIGIBLE TO MODERATE	115-145	540-28,800
KP - KAME PLAINS STRATIFIED SAND AND GRAVEL	[illegible]ABLE WITH [illegible]ALITY, MAY EXCEED 100 FEET	EASY	FAIR (SAND) TO GOOD (GRAVEL)	5°	STABLE TO ANGLE OF REPOSE. REQUIRE SUPPORT BELOW WATER TABLE	NEGLIGIBLE TO MODERATE	115-145	540-28,800

TABLE [illegible]

	THICKNESS OF UNIT	EXCAVATION CHARACTERISTICS	BEARING CAPACITY (1)	AVERAGE NATURAL SLOPE (DEG)	CUT SLOPES MAXIMUM (DEG)	COMPRESSIBILITY AND EXPANSION	UNIT DRY WEIGHT (PCF)	EXCAVATION PERMEABILITY GAL/DAY/CY
[illegible] AND [illegible] SAND [illegible] GRAVEL [illegible] SORTED	GENERALLY SEVERAL TENS OF FEET, MAY EXCEED [illegible] FEET.	EASY	FAIR (SAND) TO GOOD (GRAVEL)	5°	STABLE TO ANGLE OF REPOSE, REQUIRE SUPPORT BELOW WATER TABLE	NEGLIGIBLE TO MODERATE	115-145	540-28,800
[illegible] OUTWASH PLAINS, GENERALLY WELL SORTED SANDS AND GRAVELS WITH LENSES OF COARSER AND FINER MATERIAL.	GENERALLY MORE THAN 25 FEET; MAY EXCEED SEVERAL HUNDRED FEET	EASY. OFTEN REQUIRES DEWATERING BEFORE EXCAVATION.	FAIR (SAND) TO GOOD (GRAVEL). MAY SETTLE WITH VIBRATORY LOADING.	5°	STABLE TO ANGLE OF REPOSE, REQUIRE SUPPORT BELOW WATER TABLE.	NEGLIGIBLE TO MODERATE	1,5-145	OFTEN GREATER THAN 10,000
S - SWAMP DEPOSIT SILT AND SAND AND CLAY WITH ORGANIC MATTER.	GENERALLY THIN. LESS THAN 15 FT.	EASY	POOR	2°	UNSTABLE. FLOWS READILY INTO UNDERWATER EXCAVATIONS	MEDIUM TO HIGH	90-130	1-20
SU - SAND AND GRAVEL, UNDIFFERENTIATED VARIOUS DEPOSITS OF SORTED AND UNSORTED SAND AND GRAVEL	GENERAL CATEGORY, VARIABLE TO SEVERAL TENS OF FEET	EASY	FAIR (SAND) TO GOOD (GRAVEL)	5°	STABLE TO ANGLE OF REPOSE, REQUIRE SUPPORT BELOW WATER TABLE.	NEGLIGIBLE TO MODERATE	115-145	540-28 800

1. RANGES OF VALUES FOR BEARING CAPACITY (TONS PER SQUARE FEET).

VERY POOR	LESS THAN 1
POOR	1 - 4
FAIR	4 - 8
GOOD	8 - 32
EXCELLENT	GREATER THAN 32

TABLE [illegible]

SELECTED ENGINEERING CHARACTERISTICS OF ROCK FORMATIONS

FORMATION DESCRIPTION	EXCAVATION CHARACTERISTICS	COMPRESSIVE STRENGTH PSI	DRY UNIT WEIGHT PCF	DURABILITY	YOUNGS MODULUS OF ELASTICITY	SURFACE BEARING CAPACITY T.S.F.(AVE)	EXCAVATION DIFFICULTY	SOURCE OF CONSTRUCTION MATERIAL
AGP - ABSALONA FORMATION GRAY BIOTITE GNEISS WITH QUARTZ-BIOTITE SCHIST INCLUSIONS AND QUARTZ-EPIDOTE NODULES, WELL DEVELOPED FOLIATION	DIRECTIONAL STABILITY, MODERATELY HARD EXCAVATION, SHAPING CONTROLLED BY FOLIATION	LOW TO MEDIUM	[illegible]-176	GOOD TO VERY GOOD	LOW (SCHIST) TO HIGH (GNEISS)	40	LOW TO MODERATELY HIGH ACCORDING TO ROCK STRUCTURE	FAIR TO POOR
B - BLACKSTONE SERIES, UNDIFFERENTIATED QUARTZITE, VARIOUS SCHISTS AND GNEISSES	DIRECTIONAL STABILITY, MODERATELY HARD EXCAVATION, SHAPING CONTROLLED BY FOLIATION.	VERY LOW TO MEDIUM	[illegible]	GOOD TO VERY GOOD	LOW TO HIGH (QUARTZITE)	40	LOW TO MODERATELY HIGH DEPENDING ON ORIENTATION OF ROCK STRUCTURE	FAIR TO POOR
BHG - HUNTING HILL GREENSTONE MASSIVE TO SCHISTOSE, VEINS OF EPIDOTE COMMON	DIRECTIONAL STABILITY, MODERATELY HARD EXCAVATION, SHAPING CONTROLLED BY FOLIATION	VERY LOW TO MEDIUM	[illegible]-181	GOOD TO VERY GOOD	LOW	40	LOW	POOR
BMI - BLACKSTONE SERIES MIGMATITE CHIEFLY GRAY QUARTZ-MICA SCHIST AND QUARTZITE WITH SMALL GRANITE, APLITE AND PEGMATITE STRINGERS.	DIRECTIONAL STABILITY, MODERATELY HARD EXCAVATION, SHAPING CONTROLLED BY FOLIATION.	LOW TO HIGH	162-173	GOOD TO VERY GOOD	MEDIUM TO HIGH	40	LOW TO MODERATELY HIGH DEPENDING ON ORIENTATION OF ROCK STRUCTURE	FAIR TO POOR
BMS - MUSSEY BROOK SCHIST CHIEFLY GREENISH CHLORITE-QUARTZ SCHIST AND ALSO QUARTZITE, THIN BEDDED.	DIRECTIONAL STABILITY, MODERATELY HARD EXCAVATION, SHAPING CONTROLLED BY FOLIATION.	VERY LOW TO MEDIUM	165-[illegible]	GOOD TO VERY GOOD	LOW	40	LOW	POOR

TABLE 6-7

FORMATION DESCRIPTION	EXCAVATION CHARACTERISTICS	COMPRESSIVE STRENGTH PSI	DRY UNIT WEIGHT PCF	DURABILITY	YOUNGS MODULUS OF ELASTICITY	SURFACE BEARING CAPACITY T.S.F. (AVE)	EXCAVATION DIFFICULTY	SOURCE OF CONSTRUCTION MATERIAL
BQ - QUARTZITE BEDS GRAY QUARTZITE	DIFFICULT EXCAVATION, SHAPING CONTROLLED BY STRUCTURE	MEDIUM TO HIGH	[illegible]-172	VERY GOOD	HIGH	40	MODERATELY HIGH	GOOD TO FAIR
BOQ - QUINVILLE QUARTZITE BLUE-GRAY TO GRAY QUARTZITE WITH INTERBEDDED QUARTZ-MICA SCHIST; MASSIVE TO THIN-BEDDED.	STABILITY AND SHAPING CONTROLLED BY STRUCTURE. MODERATELY HARD EXCAVATION.	MEDIUM TO HIGH	165-172	VERY GOOD	HIGH TO LOW (SCHIST)	40	MODERATELY HIGH TO HIGH	GOOD TO FAIR
BSP - SNEECH POND SCHIST GRAY TO GREEN QUARTZ-MICA SCHIST WITH QUARTZITE, GREENSTONE AND MARBLE INTERBEDS; SCHISTOSE TO MASSIVE.	DIRECTIONAL STABILITY, MODERATELY HARD EXCAVATION, SHAPING CONTROLLED BY FOLIATION.	VERY LOW TO MEDIUM	165-181	GOOD TO VERY GOOD	LOW TO HIGH (QUARTZITE)	40	LOW	POOR
CFG - FINE-GRAINED GRANITE (RELATED TO COWESETT GRANITE) GRAY; FINE-GRAINED; MOSTLY MASSIVE	UNIFORM STABILITY, DIFFICULT EXCAVATION, EFFECTIVE SHAPING.	MEDIUM TO VERY HIGH	162-173	GOOD TO EXCELLENT	LOW TO MEDIUM	100	HIGH	GOOD TO EXCELLENT
CG - COWESSETT GRANITE GRAY TO PINK, MEDIUM-TO COARSE GRAINED; MAINLY MASSIVE.	UNIFORM STABILITY, DIFFICULT EXCAVATION, EFFECTIVE SHAPING.	MEDIUM TO VERY HIGH	162-173	GOOD TO EXCELLENT	LOW TO MEDIUM	100	HIGH	GOOD TO EXCELLENT
CGP - GRANITE PORPHRY ASSOCIATED WITH COWESETT GRANITE GRAY TO PINK; FINE-TO MEDIUM-GRAINED; MASSIVE.	UNIFORM STABILITY, DIFFICULT EXCAVATION, EFFECTIVE SHAPING.	MEDIUM TO VERY HIGH	162-173	GOOD TO EXCELLENT	LOW TO MEDIUM	100	HIGH	GOOD TO EXCELLENT

TABLE [illegible]

FORMATION DESCRIPTION	EXCAVATION CHARACTERISTICS	COMPRESSIVE STRENGTH PSI	DRY UNIT WEIGHT PCF	DURABILITY	YOUNGS MODULUS OF ELASTICITY	SURFACE BEARING CAPACITY T.S.F. (AVE)	EXCAVATION DIFFICULTY	SOURCE OF CONSTRUCTION MATERIAL
CMG - MASKERCHUGG GRANITE GRAY TO TAN; FINE GRAINED; WELL-DEVELOPED FLOW STRUCTURE	UNIFORM STABILITY. DIFFICULT EXCAVATION. EFFECTIVE SHAPING.	MEDIUM TO VERY HIGH	162-173	GOOD TO EXCELLENT	LOW TO MEDIUM	100	HIGH	GOOD TO EXCELLENT
CPG - COWESETT GRANITE (PERTHITIC) GRAY; COARSE-TO MEDIUM GRAINED. MASSIVE AND WITH FLOW STRUCTURE.	UNIFORM STABILITY. DIFFICULT EXCAVATION. EFFECTIVE SHAPING.	MEDIUM TO VERY HIGH	162-173	GOOD TO EXCELLENT	LOW TO MEDIUM	100	HIGH	GOOD TO EXCELLENT
EG - ESMOND GRANITE GRAY, PINK AND TAN; MEDIUM-TO COARSE GRAINED; MASSIVE TO FOLIATED.	UNIFORM STABILITY. DIFFICULT EXCAVATION. EFFECTIVE SHAPING.	MEDIUM TO VERY HIGH	162-173	GOOD TO EXCELLENT	LOW TO MEDIUM	100	HIGH	GOOD TO EXCELLENT
GMG - GRANT MILLS GRANODIORITE GRAY; MASSIVE TO FOLIATED AND STREAKY.	UNIFORM OR DIRECTIONAL STABILITY. DIFFICULT EXCAVATION. EFFECTIVE SHAPING.	MEDIUM TO VERY HIGH	162-173	GOOD TO EXCELLENT	LOW TO MEDIUM	100 (MASSIVE) 40 (FOLIATED)	MODERATELY HIGH TO HIGH ACCORDING TO ROCK STRUCTURE	GOOD TO POOR
HVA - HOPE VALLEY ALASKITE GNEISS MOSTLY PINK OR TAN, ALSO GRAY; QUARTZ LINEATIONS.	DIRECTIONAL STABILITY. MODERATELY HARD EXCAVATION. SHAPING CONTROLLED BY FOLIATION.	MEDIUM TO VERY HIGH	162-173	GOOD TO VERY GOOD	LOW TO MEDIUM	100	LOW TO MODERATELY HIGH ACCORDING TO ROCK STRUCTURE	FAIR TO POOR
LGN - LIGHT-COLORED GNEISS OF NORTHWESTERN RHODE ISLAND GRAY DISTINCTLY FOLIATED.	DIRECTIONAL STABILITY. MODERATELY HARD EXCAVATION. SHAPING CONTROLLED BY FOLIATION.	LOW TO MEDIUM	166-175	GOOD TO VERY GOOD	HIGH	40	LOW TO MODERATELY HIGH ACCORDING TO ROCK STRUCTURE	FAIR TO POOR

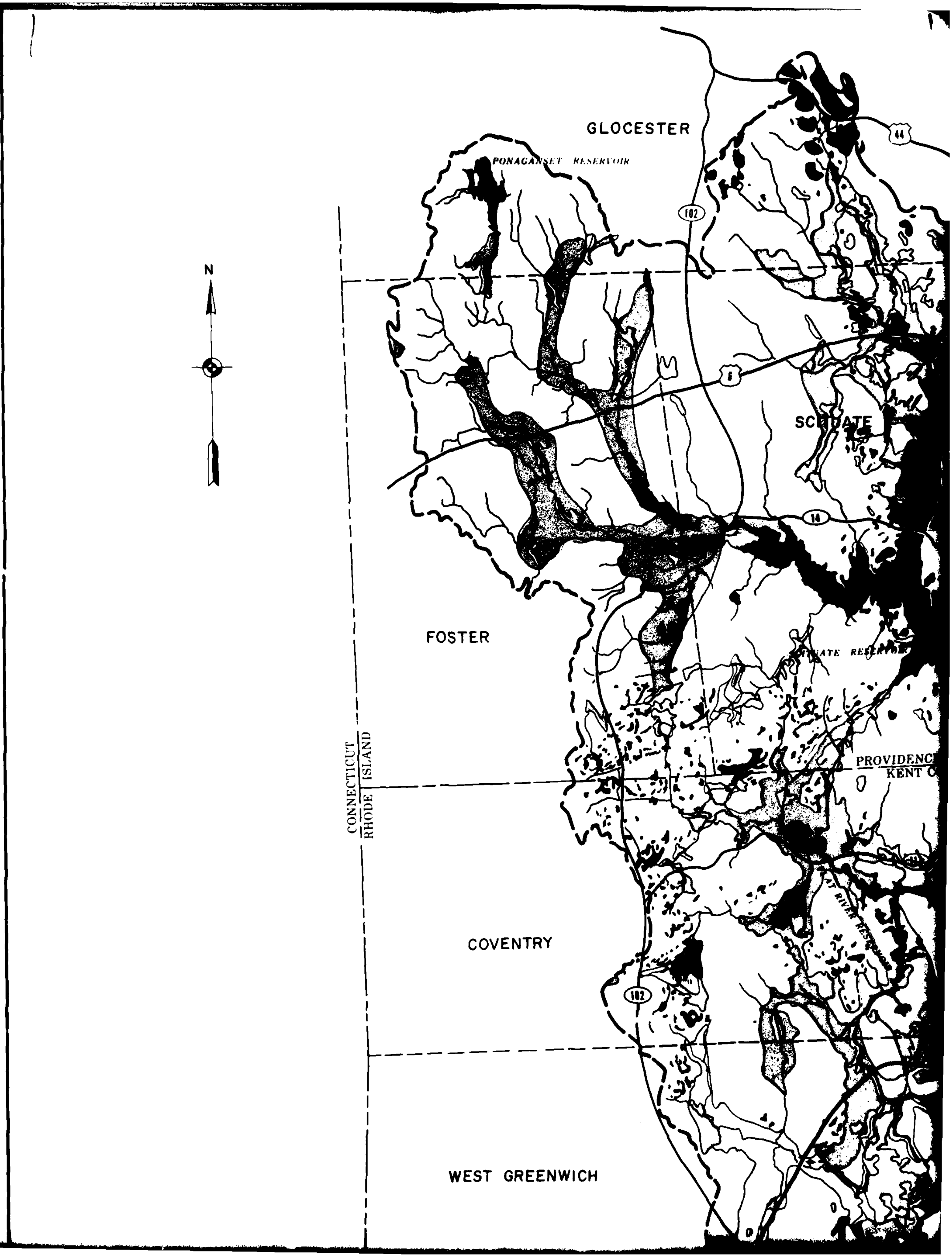
TABLE [illegible]

FORMATION DESCRIPTION	EXCAVATION CHARACTERISTICS	COMPRESSIVE STRENGTH PSI	DRY UNIT WEIGHT PCF	DURABILITY	YOUNGS MODULUS OF ELASTICITY	SURFACE BEARING CAPACITY T.S.F.(AVE)	EXCAVATION DIFFICULTY	SOURCE OF CONSTRUCTION MATERIAL
QD- QUARTZ DIORITE GRAY, VARIABLE FOLIATION	DIRECTIONAL STABILITY. MODERATELY HARD EXCAVATION. SHAPING CONTROLLED BY FOLIATION.	HIGH	181-193	GOOD TO EXCELLENT	LOW TO HIGH	100	MODERATELY HIGH	FAIR TO POOR
SQ - SCITUATE GRANITE GNEISS PINKISH, TAN AND GRAY, STRONG BIOTITIC LINEATIONS AND SOME FOLIATION	DIRECTIONAL STABILITY. MODERATELY HARD EXCAVATION. SHAPING CONTROLLED BY FOLIATION.	MEDIUM TO VERY HIGH	162-173	GOOD TO EXCELLENT	LOW TO MEDIUM	100	MODERATELY HIGH TO HIGH ACCORDING TO ROCK STRUCTURE	FAIR TO POOR
SGF - FINE-GRAINED GRANITE (RELATED TO SCITUATE GRANITE GNEISS AND TEN ROD GRANITE GNEISS) GRAY, PINK AND TAN; FINE-GRAINED, MASSIVE BUT COMMONLY WITH BIOTITIC LINEATIONS	UNIFORM STABILITY DIFFICULT EXCAVATION, EFFECTIVE SHAPING.	MEDIUM TO VERY HIGH	162-173	GOOD TO EXCELLENT	LOW TO MEDIUM	• 100	HIGH	GOOD TO EXCELLENT
SHV - SPENCER HILL VOLCANICS INTERBEDDED RHYOLITE FLOWS, PYROCLASTIC ROCK AND CONGLOMERATE, WELL-DEVELOPED FLOW STRUCTURE.	DIRECTIONAL STABILITY. MODERATELY HARD EXCAVATION. SHAPING CONTROLLED BY STRUCTURE.	HIGH	164-172	VERY GOOD	HIGH	40	MODERATELY HIGH	POOR TO GOOD
TGR - TEN ROD GRANITE GNEISS GRAY TO PINK; MODERATE TO STRONG FOLIATION AND LINEATION	DIRECTIONAL STABILITY. MODERATELY HARD EXCAVATION. SHAPING CONTROLLED BY FOLIATION.	MEDIUM TO VERY HIGH	162-173	GOOD TO VERY GOOD	LOW TO MEDIUM	100 (MASSIVE) 40 (FOLIATED)	LOW TO MODERATELY HIGH ACCORDING TO ROCK STRUCTURE	FAIR TO POOR
WGN - WOONASQUATUCKET FORMATION LIGHT GRAY GNEISS AND SCHIST, INDISTINCTLY FOLIATED AND LAYERED	DIRECTIONAL STABILITY. MODERATELY HARD EXCAVATION. SHAPING CONTROLLED BY FOLIATION.	LOW TO MEDIUM	166-176	GOOD TO VERY GOOD	LOW (SCHIST) TO HIGH (GNEISS)	40	LOW TO MODERATELY HIGH	FAIR TO POOR

TABLE G-2

TABLE [illegible]

FORMATION DESCRIPTION	EXCAVATION CHARACTERISTICS	COMPRESSIVE STRENGTH PSI	DRY UNIT WEIGHT PCF	DURABILITY	YOUNGS MODULUS OF ELASTICITY	SURFACE BEARING CAPACITY T.S.F. (AVE)	EXCAVATION DIFFICULTY	SOURCE OF CONSTRUCTION MATERIAL
MD - METADIORITE MAINLY GRAY BUT ALSO GREEN DIORITE AND METADIORITE; MASSIVE TO SCHISTOSE; SOME AMPHIBOLITE.	DIRECTIONAL STABILITY. MODERATELY HARD EXCAVATION. SHAPING CONTROLLED BY FOLIATION	HIGH	181-193	GOOD TO VERY GOOD	LOW TO HIGH	40	MODERATELY HIGH TO HIGH ACCORDING TO ROCK STRUCTURE	FAIR TO POOR
PB - BELLINGHAM CONGLOMERATE INCLUDES GRAY TO GREEN CONGLOMERATE, SANDSTONE, GRAYWACKE AND PHYLLITE; IRREGULARLY INTERBEDDED	STABILITY AND SHAPING CONTROLLED BY STRUCTURE. HARD TO MODERATELY HARD EXCAVATION.	MEDIUM TO HIGH	165-168	GOOD TO VERY GOOD	HIGH	15	MODERATELY HIGH TO HIGH	POOR TO FAIR
PGN - PONAGANSET GNEISS GRAY; VARIABLE, STRONGLY FOLIATED AND LINEATED.	DIRECTIONAL STABILITY. MODERATELY HARD EXCAVATION. SHAPING CONTROLLED BY FOLIATION.	MEDIUM TO VERY HIGH	162-173	GOOD TO VERY GOOD	LOW TO MEDIUM	40	LOW TO MODERATELY HIGH ACCORDING TO ROCK STRUCTURE	FAIR TO POOR
PP - PONDVILLE CONGLOMERATE GRAY TO GREENISH CONGLOMERATE WITH SANDSTONE AND GRAYWACKE INTERBEDS. PEBBLES AND COBBLES COMMON.	STABILITY AND SHAPING CONTROLLED BY STRUCTURE. HARD TO MODERATELY HARD EXCAVATION.	MEDIUM TO HIGH	165-168	GOOD TO VERY GOOD	HIGH	15	MODERATELY HIGH TO HIGH	POOR TO FAIR
PRI - RHODE ISLAND FORMATION GRAY SANDSTONE AND GRAYWACKE, AND DARK GRAY AND BLACK SHALE; SOME CONGLOMERATE AND META-ANTHRACITE; CROSSBEDDED AND IRREGULAR DISCONTINUOUS BEDDING; UNMETAMORPHOSED IN THE NORTH. METAMORPHIC CLEAVAGE AND SCHISTOSITY APPEAR SOUTHWARD.	DIRECTIONAL STABILITY. EASY EXCAVATION. SHAPING HIGHLY DEPENDENT ON STRATIFICATION.	VERY LOW (SHALE) TO HIGH (SANDSTONE)	135-162	POOR TO GOOD	VERY LOW TO LOW	15	LOW	POOR



N
GLOCESTER
PONAGANSET RESERVOIR
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102
6
SCITUATE
14
FOSTER
SCITUATE RESERVOIR
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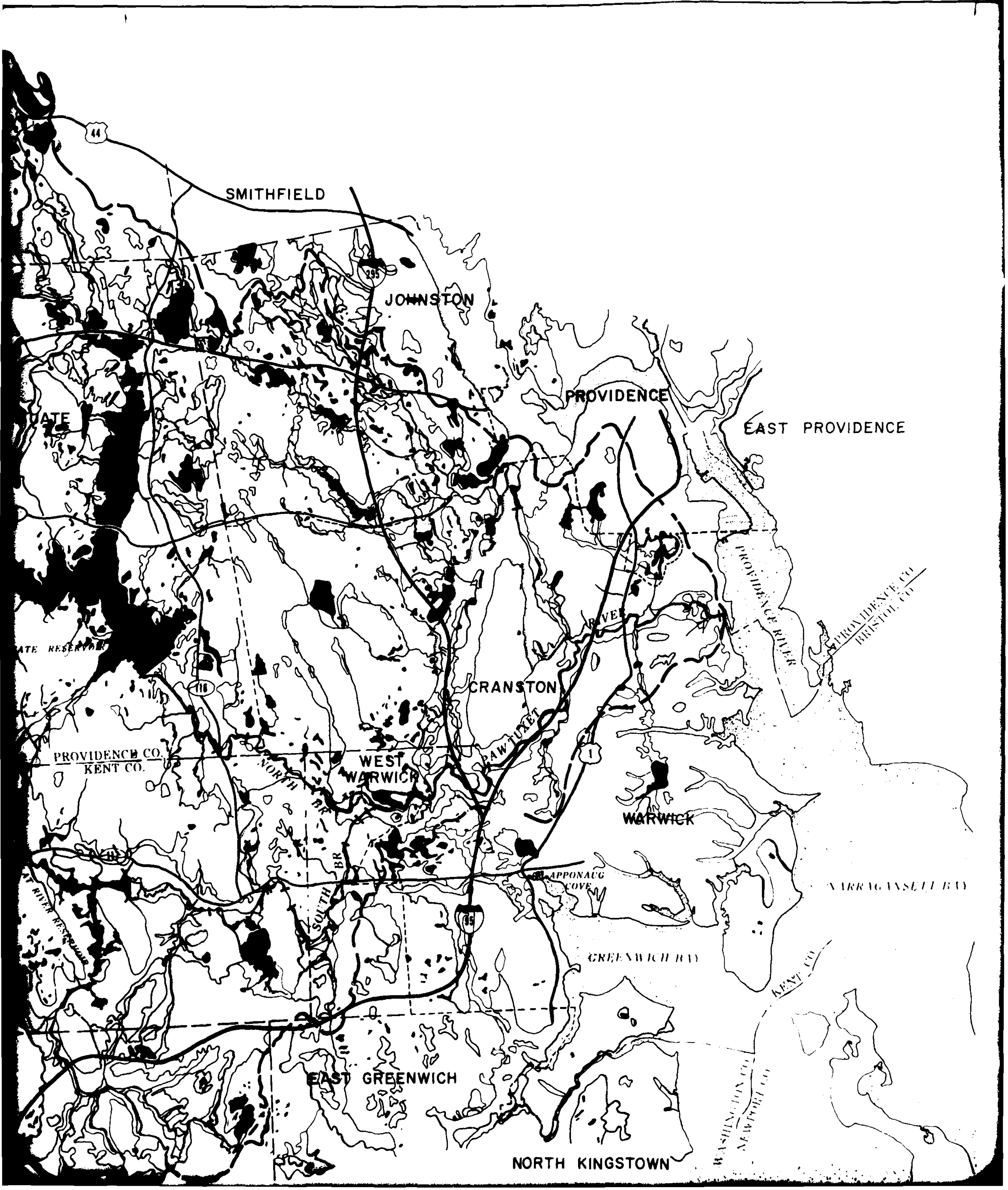
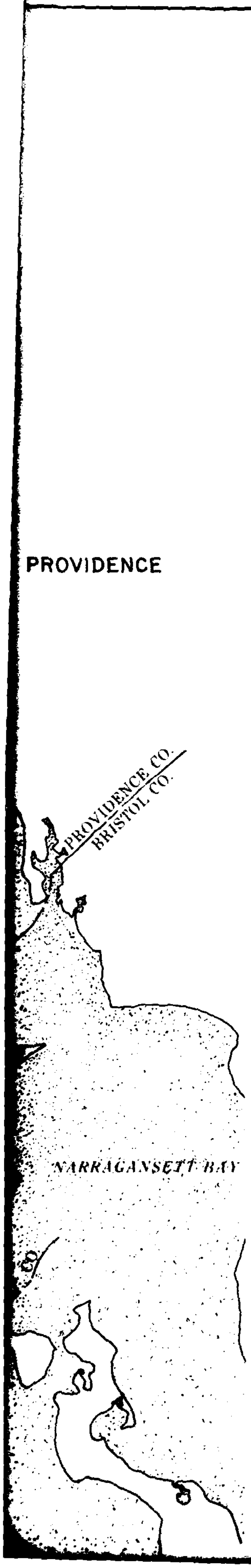
RHODE ISLAND
PROVIDENCE
KENT C
COVENTRY
102
WEST GREENWICH



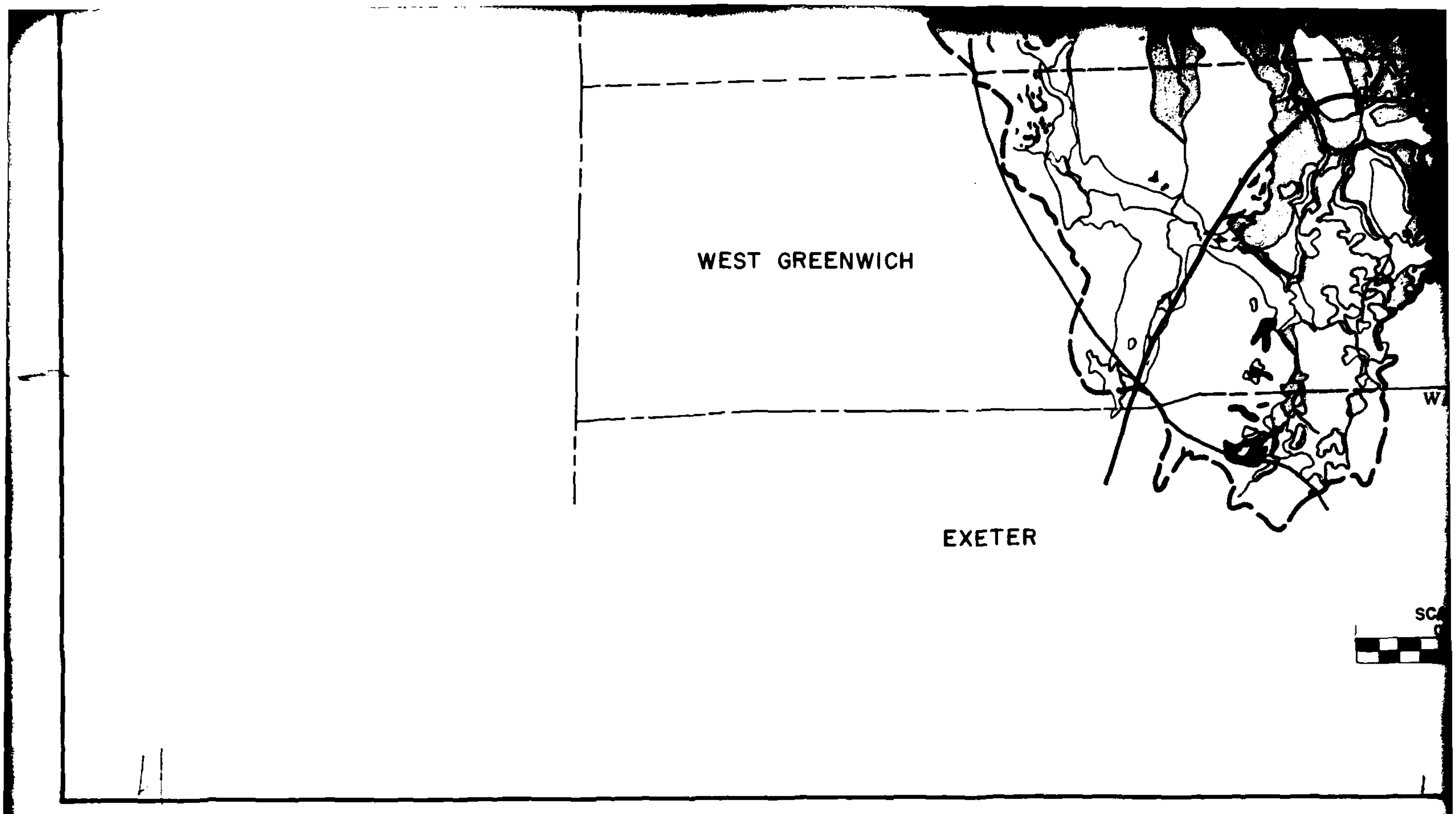
44
SMITHFIELD
295
JOHNSTON
PROVIDENCE
EAST PROVIDENCE
CRANSTON
RIVER
PAWTUXET
116
PROVIDENCE CO.
KENT CO.
WEST WARWICK
NORTH BR
SOUTH BR
1
WARWICK
APPONAUG COVE
95
GREENWICH BAY
NARRAGANSETT BAY
PROVIDENCE RIVER
PROVIDENCE CO.
BRISTOL CO.
KENT CO.
EAST GREENWICH
NORTH KINGSTOWN
WASHINGTON CO.
NEWPORT CO.



LOCATION MAP

SCALE IN MILES
0 10 20 30 40 50

s	*Sand and gravel, undifferentiated*
al	*Alluvium*
	Kames, kame plains , kame terraces and valley train deposits
op	*Outwash plains*
	Swamp deposits silt, sand, and partially decayed organic material
gm	*Ground moraine (glacial till)*
	Artificial fill
	Bedrock outcrops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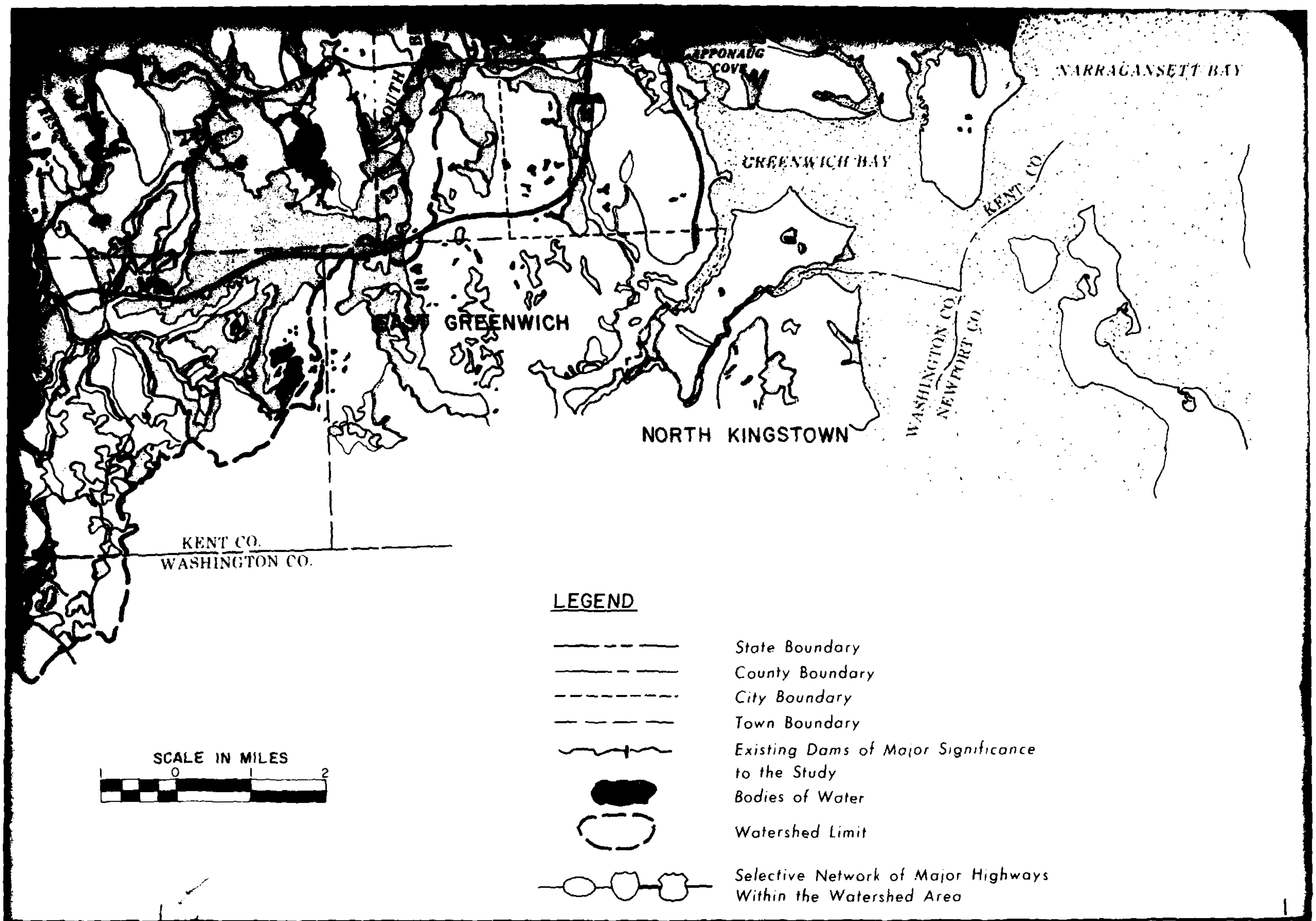
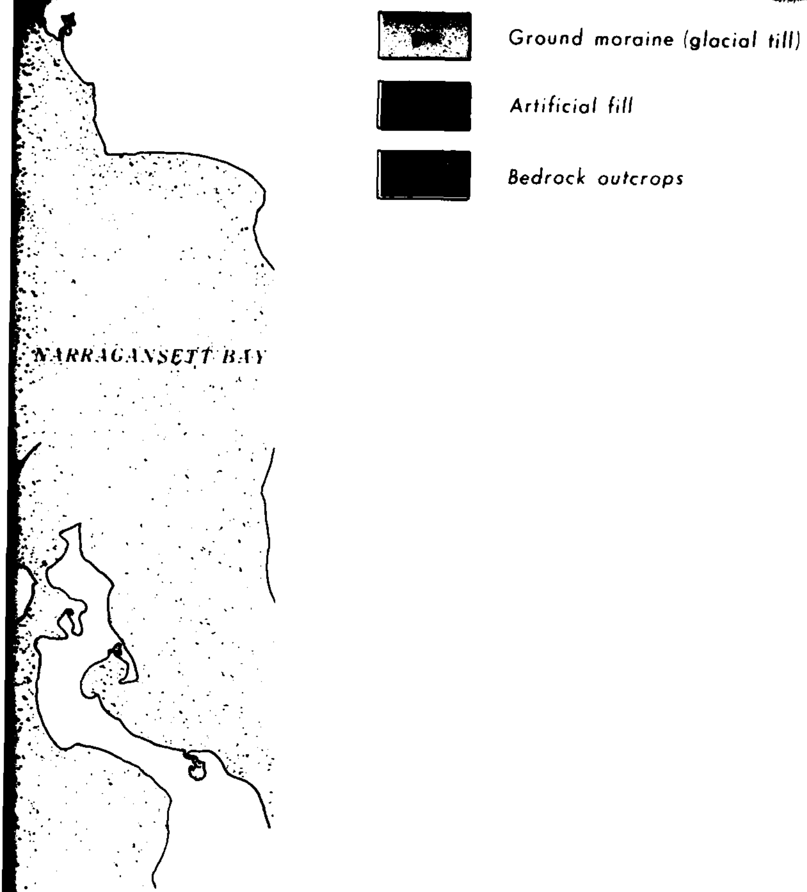
EXETER


APPONAUG COVE
NARRAGANSETT BAY
GREENWICH BAY
KENT CO.
EAST GREENWICH
NORTH KINGSTOWN
WASHINGTON CO.
NEWPORT CO.
KENT CO.
WASHINGTON CO.
LEGEND
State Boundary
County Boundary
City Boundary
Town Boundary
Existing Dams of Major Significance to the Study
Bodies of Water
Watershed Limit
Selective Network of Major Highways Within the Watershed Area
SCALE IN MILES
1 0 1 2



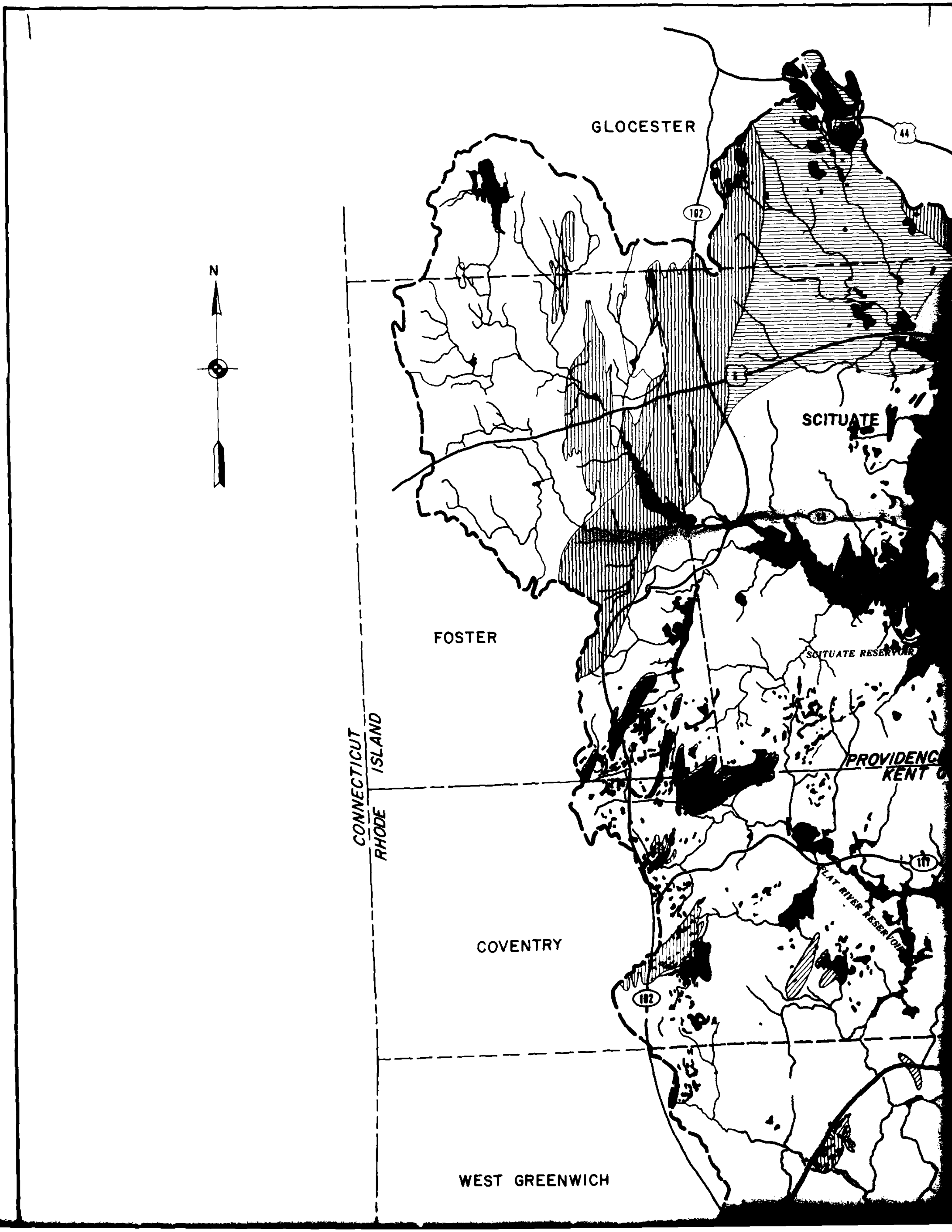
WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

SURFICIAL GEOLOGY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE G-1


GLOCESTER
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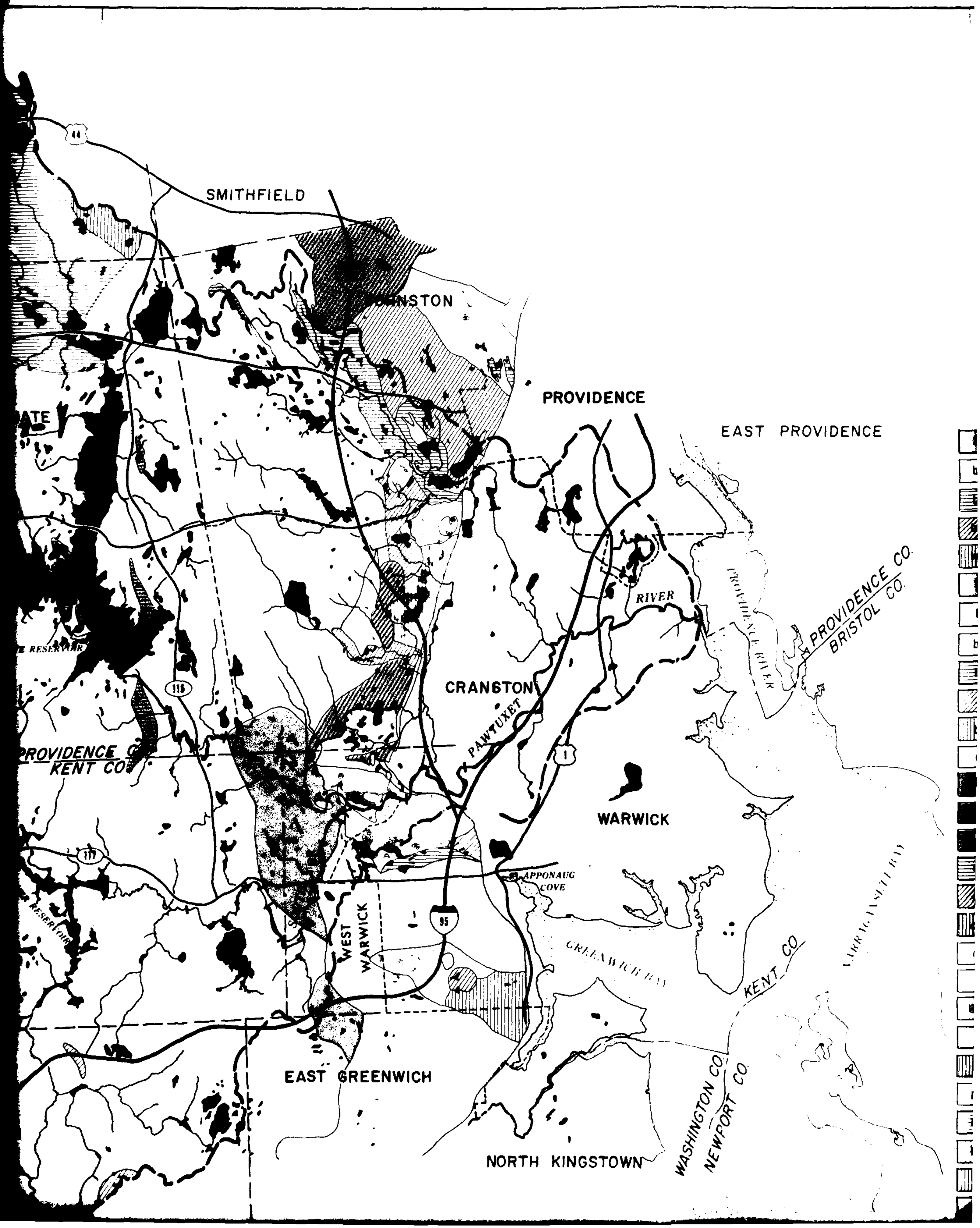
SCITUATE
6
FOSTER
SCITUATE RESERVOIR
CONNECTICUT
RHODE ISLAND
PROVIDENC
KENT C
117
FLAT RIVER RESERVOIR
COVENTRY
102
WEST GREENWICH


SMITHFIELD
JOHNSTON
PROVIDENCE
EAST PROVIDENCE
CRANSTON
PAWTUXET
RIVER
PROVIDENCE RIVER
PROVIDENCE CO.
BRISTOL CO.
PROVIDENCE CO.
KENT CO.
WARWICK
APPONAUG COVE
WEST WARWICK
GREENWICH BAY
NARRAGANSETT BAY
KENT CO.
WASHINGTON CO.
NEWPORT CO.
EAST GREENWICH
NORTH KINGSTOWN
RESERVOIR
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116
117
95
1

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BIG RIVER RESERVOIR PROJECT - PAWCATUCK RIVER AND NARRAGANSETT --ETC(U)
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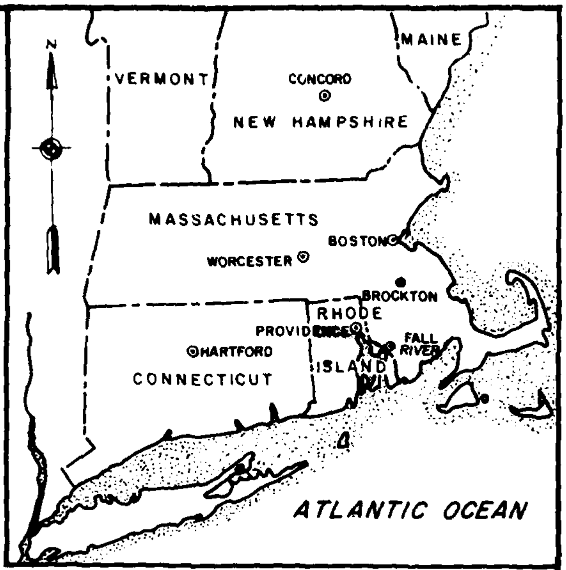
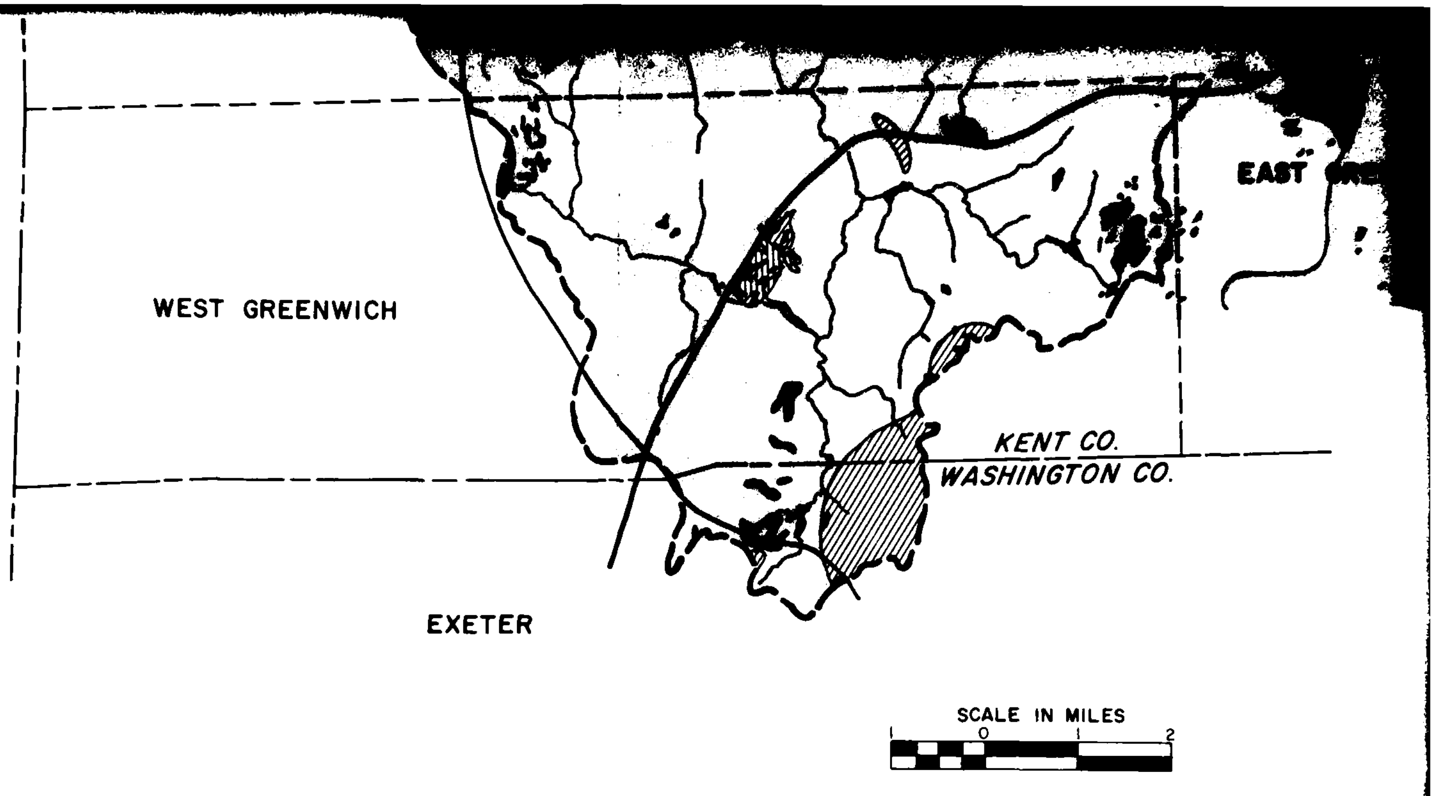


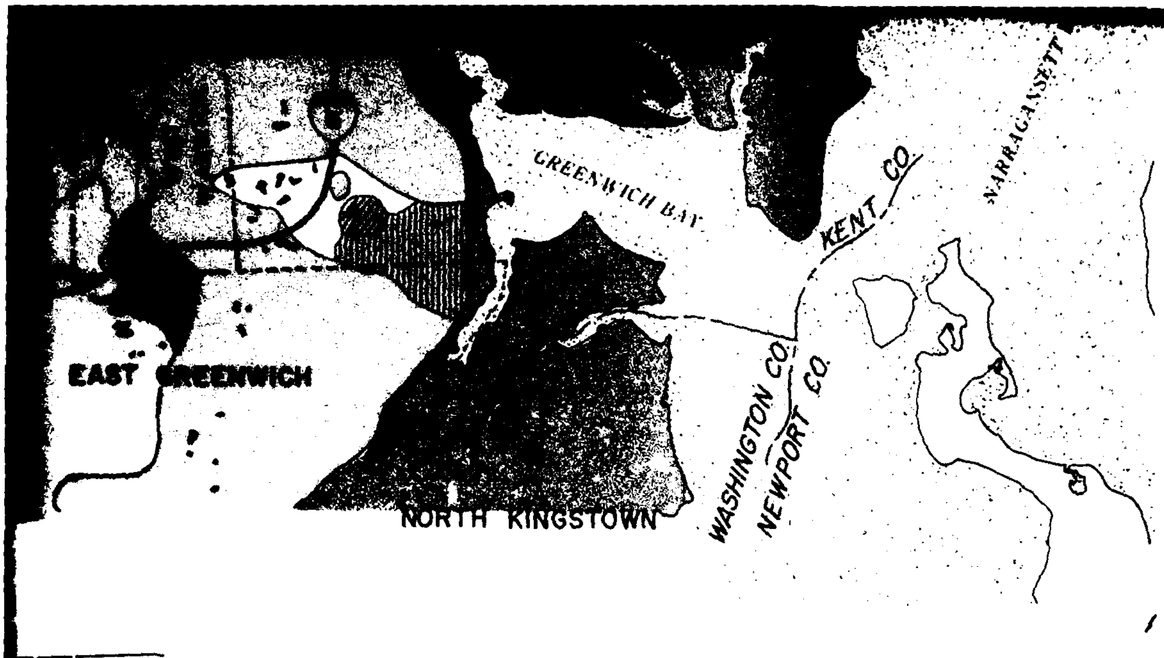
LOCATION MAP

SCALE IN MILES
0 10 20 30 40 50

- Rhode Island Formation
- bsp — Sneech Pond Schist
- Hunting Hill Greenstone
- Mussey Brook Schist
- Woonasquatucket Formation
- Bellingham Conglomerate
- Pp — Pondville Conglomerate
- bqq — Quinville Quartzite
- Quartzite beds
- Blackstone Series, undifferentiated
- Blackstone Series Migmatite
- Cowesett Granite
- Cowesett Granite (perthitic facies)
- Esmond Granite
- *Fine-grained granite related to Scituate Granite Gneiss and Ten Rod Granite Gneiss*
- Fine-grained granite related to Cowesett Granite
- Granite porphry associated with Cowesett Granite
- Maskerchugg Granite
- md — Metadiorite
- qd — Quartz diorite
- Grant Mills Granodiorite
- Scituate Granite Gneiss
- Light-colored gneiss of northwestern Rhode Island
- pgn — Ponaganset Gneiss
- Absalona Formation
- Hope Valley Alaskite Gneiss
- **Ten Rod Granite Gneiss**



WEST GREENWICH
EAST GRE
KENT CO.
WASHINGTON CO.
EXETER
SCALE IN MILES
1 0 1 2



Fine-grained granite related to Co
Granite porphry associated with Co
Maskerchugg Granite
md Metadiorite
qd Quartz diorite
gmg Grant Mills Granodiorite
sg Scituate Granite Gneiss
Light-colored gneiss of northwestern
pgn Ponaganset Gneiss
apg Absalona Formation
hvg Hope Valley Alaskite Gneiss
trg Ten Rod Granite Gneiss
shv Spencer Hill Volcanics
Bedrock outcrops

LEGEND

State Boundary
County Boundary
City Boundary
Town Boundary
Existing Dams of Major Significance to the Study
Bodies of Water
Watershed Limit
Selective Network of Major Highways

WATER RESOURCES MANAGEMEN

PAWTUXET RIVER BAS
RHODE ISLAND

BEDROCK GEOLOGY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENG
WALTHAM, MASS.

	Fine-grained granite related to Scituate Granite Gneiss and Ten Rod Granite Gneiss
	Fine-grained granite related to Cowesett *Granite*
	Granite porphyry associated with Cowesett *Granite*
	Maskerchugg Granite
md	Metadiorite
qd	Quartz diorite
	Grant Mills Granodiorite
	Scituate Granite Gneiss
	Light-colored gneiss of northwestern Rhode Island
pgn	Ponaganset Gneiss
	Absalona Formation
	Hope Valley Alaskite Gneiss
	Ten Rod Granite Gneiss
shv	Spencer Hill Volcanics
	Bedrock outcrops

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

BEDROCK GEOLOGY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE G-2

APPENDIX 5

RECREATION & NATURAL

RESOURCES

TABLE OF CONTENTS

RECREATION AND NATURAL RESOURCES APPENDIX

The State of Rhode Island has identified the major concerns for recreation and natural resources of the region. The detailed analysis is found the Plan for Recreation, Conservation and Open Space, June 1978. This plan also serves as Rhode Island's Statewide Comprehensive Outdoor Recreation Plan (SCORP). The most important highlights of the plan will be cited here, followed by discussion of the impacts that the different alternative plans would have on recreation and natural resources.

In the Statewide Plan the following general goals were established to guide the formulation of all plans and implementation programs concerning recreation and natural resources:

1. Provide for adequate and diverse recreational opportunities and facilities primarily to meet the needs of the State's residents while also attracting and serving visitors.

2. Preserve and protect open space so as to enhance the total quality of the environment.

3. Insure the sound use and development of appropriate land and water resources in Rhode Island for recreational purposes.

4. Recognize that Narragansett Bay is the State's most important natural feature and recreational resource.

5. Improve the capability of both public and private sectors to respond to recreational needs at both the community and regional levels within the State.

6. Utilize, to the greatest extent possible, the capabilities of the private sector in the outdoor recreational area.

7. Improve opportunities for water-oriented recreation by reducing pollution and controlling water quality in Rhode Island's water bodies.

A number of key recommendations were formulated to help meet these established goals. Those recommendations that are most pertinent to the project area are as follows:

* Improve use opportunities at existing urban and metropolitan parks and develop additional neighborhood recreation areas.

* Improve public transportation to recreation sites particularly in and around urban areas.

* Provide fresh water swimming principally in the west and east metropolitan regions, not only to meet supply deficiencies but also as a substitute for salt-water swimming.

* Adopt a formal arrangement between the Rhode Island Historical Preservation Commission and the Department of Environmental Management for the purpose of facilitating the orderly development of areas that have both historic and recreational significance.

* Complete a feasibility study for the establishment of a scenic and recreational river system in the State.

* Meet picnicking deficiencies in all regions, and particularly the West Metropolitan and Northeast regions.

* Meet Statewide supply deficiencies in tennis. These are most acute in the West Metropolitan and Northeast regions.

* Activity in many recreation pursuits should be stimulated by government through the provision of accessible facilities and through the promotion of those recreational pursuits that exhibit multi-season durability.

* The Statewide Planning Program should complete its flood plain management study and examine alternative protection and regulation techniques for flood prone areas.

* Investigate legal provisions which create conflicts between private ownership and the recreational use of the State's navigable waterways. Clarify public regulations for recreational use of navigable waterways.

* Identify, publicize, and protect areas of scenic, historical, and cultural interest for the large sightseeing population.

* For the promotion of environmental awareness, encourage the Department of Education to foster the use and study of appropriate natural areas as part of the educational curriculum in all school districts.

In order to access regional recreation and natural resource problems and needs, the State used a number of different survey techniques. Various questionnaires and phone calls were utilized in order to compile and understand the recreation needs and concerns of the State. These surveys yielded a number of general conclusions which form a framework for future recreation planning. Numerous activities were surveyed, with the five most popular by order of popularity being:

1. saltwater swimming
2. freshwater swimming
3. sightseeing
4. picnicking
5. outdoor games

Rhode Island's most abundant recreation resource is its salt water, providing for swimming, fishing and boating. A person's income level has a direct affect on how many activities he engages in. Also accessibility and car ownership affect ones rate of participation.

The surveys also provided valuable information on the supply and demand for recreation facilities. It was discovered that people in general will travel to the closest available supply (this implies that there is overcrowding of facilities in and around population centers). Also, people tend to travel shorter distances and will tend to participate if supply is close at hand. Surveys and models have shown that supply of recreation facilities is distributed unevenly in relation to the demand. With the exception of tennis and picnicking it was revealed that there is a surplus of supply on a Statewide basis for the most popular activities. In addition, demand for a certain activity is affected by location of supply and also quality of facilities and fees charged.

Season and time of the year are other factors which affect selection of recreation activities. Analysis showed an overwhelming preference for summer periods. The State identifies a definite need for improvement in non-summer participation rates. Ice skating has proved to be the most popular of winter activities. Other general conclusions of the surveys showed:

- Young people tend to recreate more than other people, and they tend to participate in more strenuous activities.

- Bicycling is growing in popularity and shows a significant potential for the future.

- Boating is Rhode Island's fasting growing recreation activity.

- In the West Metropolitan region, the project area, there is a deficiency of freshwater swimming.

IMPACT OF ALTERNATIVES ON RECREATION AND NATURAL RESOURCES

None of the ten alternatives has a significant amount of recreation potential associated with it. Possible passive types of recreation (walkway, bikepath) could be incorporated into those alternatives which include the Warwick Ave Local Protection Project if the town were interested.

It is impossible at this time to assess what the recreation potential could be at the Big River Reservoir since the alternatives are only concerned with the addition of 2.5 to 3 feet of flood control storage. Most likely this peripheral land could accommodate trail development for hiking, walking, and nature study. However, a separate Survey Report is presently being prepared for the Big River Reservoir site. A recreation and natural resource appendix will accompany the study, which will analyze the recreation potential for the entire project.

The alternative plans which include the Norwood Land Bank could have an indirect impact on recreation. If homes are removed from this flood plain area the site has the capabilities of being developed for recreation. Facilities could be cost-shared with the Government if there was a desire expressed by the city of Warwick.

Fish and Wildlife

The fish and wildlife information which follows was prepared by the Fish and Wildlife Service during the early stages of the project. It gives a general account of those natural resources in the watershed.

Fishery Resources

Marine

Apponaug Cove at the head of Greenwich Bay serves as a forage, breeding, spawning, and nursery ground for many species of finfish and invertebrates. Finfish found in the area include winter flounder, bluefish, blueback herring, menhaden, alewife, weakfish, mummichog, striped killifish, Atlantic silversides, fourspine stickleback, smelt, eel and others.

Very little quantitative data is available concerning finfish distribution, species composition and the extent and importance of this resource to commercial and recreational fishermen. The extent of commercial fishing is somewhat limited but the sport fishery is very important in the Apponaug-Greenwich Bay area.

Commercial finfishing in Greenwich Bay is generally limited to eels, winter flounder, menhaden, and baitfish. Eels are collected in pots during summer. The extent of this fishery is unknown.

Alewives, mummichogs, striped killifish and silversides are collected for bait by both sport and commercial fishermen. The extent and value of this fishery is unknown.

The most important sport fish in the area are winter flounder, bluefish, and weakfish. The extent of recreation provided is not known. However, Greenwich Bay is described as being one of the most productive blue-fishing areas as well as other sport fishing spots of Rhode Island.

Shellfish in Apponaug Cove, of interest to man for recreational and commercial purposes, include the soft shelled clam, quahog, [illegible] clam, conch, blue crab and green crab. Shellfish beds within the cove are closed to shellfishing due to pollution caused by marinas and [illegible] point discharges near the cove and its tributaries. Apponaug Cove waters are classified as SC, suitable for fish and wildlife habitat and recreation boating. Greenwich Bay, however, is relatively unpolluted. Its waters are classified as SA, character uniformly excellent. The whole area of the Bay, supports a consistently important recreational and commercial shellfishery.

The quahog grounds are heavily worked by as many as 40 to 50 commercial hand tongers on an average day during the spring, summer, and fall. Close to half of the licensed commercial diggers (2,750) in Rhode Island utilize the Bay at one time or another during the year.

Soft-shelled clams also support a few commercial [illegible] and many recreational fishermen. One of the most productive [illegible] soft-shell clam beds in Narragansett Bay lies along the [illegible] of Greenwich Bay extending from Apponaug Cove [illegible].

Recreational shellfishing is very important [illegible] this [illegible] thirty recreational diggers and tongers can be found on the Bay on week-days while between 200-300 may be present on weekends

Water pollution has brought about the closure of many of Rhode Island's most productive shellfish beds, particularly in upper Narragansett Bay. The beds are closed to shellfishing after heavy rains when overflow from storm sewers increases pollution levels. Greenwich Bay is unpolluted and has remained open while other northern areas have been intermit-tently closed to shellfishing for periods in excess of 200 days of the year.

The economic and recreational importance of Greenwich Bay's shellfish resource is evidenced by the fact that the Rhode Island Division of Fish and Wildlife has the entire Bay under shellfish management.

Current and projected marine fishery programs in the area are essen-tially geared to protect and enhance finfish and shellfish resources. Efforts are made to prevent over-exploitation and reduce habitat degra-dation resulting from pollution and incompatible uses that eliminate productive habitat of value to the resources. Habitat that is currently

degraded by pollution, resulting in loss or underutilization of useful resources, is being reclaimed where possible.

With improved water quality, management of resources, and adequate State and Federal control of filling and dredging of estuaries and coastal marshes, marine fisheries in this area will remain a valuable natural resource for future generations. To what extent these resources would be utilized is difficult to predict. Present knowledge of the degree of utilization, the status and value of marine resources in the Apponaug Cove-Greenwich Bay area, is extremely limited. With increased population growth and more leisure time recreational and commerical exploitation of these marine resources will undoubtedly continue to increase. Because of the present and potential values of the marine fisheries resources of Greenwich Bay and its strategic location within easy access of Metropolitan Providence, a study to evaluate the status and value of the resources is essential to provide the necessary basis for the proper management, protection, and utilization of Greenwich Bay.

Anadromous

The Pawtuxet River formerly supported large runs of anadromous fish. Shad, alewives, smelt, and Atlantic salmon ascended the river and tributary streams to spawn. Early settlers of the watershed harvested the fish which added to their subsistence providing additional income during the spring and fall. The runs were eliminated by dams in the early history of the basin.

Restoration efforts were commenced in 1871 with unanimous support of the dam owners, but pollution of the waters prevented any long-lived success. Since erection of the first dams in the 1700's, all efforts to re-establish anadromous fisheries in the Pawtuxet have met with failure. Today, there are no fishways over the 28 dams constructed on the main stem of the Pawtuxet and its two major tributaries: the North and South Branches. Meshaniticut Brook is obstructed by seven dams, while the Pocasset is restricted by nine structures.

A study of the potential anadromous fishery in the Pawtuxet River was scheduled by the Rhode Island Division of Fish and Wildlife for 1976. The river was to be examined in terms of species known to have been present in the past, restorable species, and the economic importance of a revived fishery. Determination of base flow requirements to meet the needs of restored anadromous fish species during migration, breeding, and residence in the river was to follow this initial study. Unfortunately, a lack of money and manpower within the Division of Fish and Wildlife necessitated a shift of emphasis to smaller streams of higher priority. A study of the potential anadromous fishery in the Pawtuxet has been delayed indefinitely.

There is a definite interest in restoration of the historic runs of anadromous fish to the Pawtuxet River. Major interest is in the restoration of alewives and shad. Obstacles to restoration of alewives, [illegible] and to a lesser extent smelt and possibly steelhead [illegible] pollution and low flows. With [illegible] improvement, such as fish[illegible] construction, pollution abatement [illegible] flow reg[illegible] fish could once again become a valuable natural resource [illegible] of the watershed and the State.

The Pawtuxet River, except for the lower mile, has in the past been considered non-navigable. Private dams on the river [illegible], therefore, exempt from the Federal law which requires dams on navigable waterways to obtain a Federal Power Commission license. Since an FPC license for dams on the Pawtuxet has not been required in the past, conditions necessary for fishery conservation and management have, for the most part, been ignored. Features such as fishways over the dams, negotiated minimum flows, or access for sportsmen, are lacking.

In the future, all dam construction on the Pawtuxet and its tributaries will be subject to a regulatory permit program [illegible] of the Federal Water Pollution Control Act Amendments [illegible] with the Fish and Wildlife Coordination Act [illegible] officials who have regulatory jurisdiction [illegible] consult with the Regional Director, U.S. Fish and Wildlife Service, Regional Director, National Marine Fisheries [illegible] the agency responsible for fish and wildlife [illegible] which the work is to be performed. The Fish and Wildlife Service, National Marine Fisheries Service, and the State, through field investigations, will determine what conditions necessary for fishery conservation and management should be included in the permit. Features such as fishways, minimum flows, and access for sportsmen are examples. All new dams on the waterway plus any new work on existing dams which would involve dredging or filling of the waterway will become subject to Federal regulatory jurisdiction. Incorporation of features to restore and enhance the fishery of the Pawtuxet are extremely desirable in any planned development for this watershed.

Runs of anadromous fish presently occur in the Apponaug Cove area. Smelt and alewife migrate through Apponaug Cove and spawn in Gorton Pond and its outlet channel. The historic run of alewives is currently hindered by an elevated culvert located upstream of the highway 117 stream crossing. Smelt spawn just below the culvert outlet. The Rhode Island Division of Fish and Wildlife plans to provide a portable fishway at this location to aid the migration of alewife to Gorton Pond. Smelt are not expected to ascend the fishway.

Currently the run of alewife is less than 500 fish. With improved water quality and fishway, the recreational and aesthetic value of this anadromous run is expected to provide much interest and recreation for residents of the area.

Fresh Water Fisheries

The Pawtuxet River from River Point eastward to Pawtuxet Cove, a distance of 11.2 miles is heavily polluted by a variety of municipal and industrial wastes. The river has been described as "...one of the most polluted waterways in New England[1]..." and consequently supports no fishing. The lower [illegible].5 miles of the North Branch is also heavily polluted and supports little or no fishing -- above Fishville Dam, however, the Rhode Island Division of Fish and Wildlife does stock trout. The fishery in this river is limited and controlled by water released from Scituate Reservoir. A minimum flow of 14 cubic feet per second is maintained over week days, but flow is virtually shut off on weekends, except when the reservoir is full. The South Branch is also heavily polluted by muncipal and industrial wastes. It does, however, support a warm-water fishery composed primarily of largemouth bass and chain pickerel.

Meshanticut Brook is stocked with trout. Its small size is its major limiting factor. Pocasset River is relatively polluted and the stream banks developed. It does not support a sport fishery of significance.

Of the remaining 17 streams which support a sport fishery, the Ponaganset, Big and Flat Rivers are by far the most important. All support excellent trout fisheries, which are supplemented annually by stocking approximately 5,700 brown, rainbow and brook trout.

In addition to significant stream fisheries, there are approximately 38 ponds within the watershed, 10 acres and over in size, which support warm and cold water fisheries. Four ponds (3,942 acres), support predominantly cold water fisheries. Only Hopkins Mill Pond (16 acres), however, is currently stocked with trout and open to public fishing.

Thirty-four ponds (2,769 acres) are primarily suited for warm-water species. Flat River reservoir is the most outstanding warm-water fishery and may be stocked with northern pike in the near future.

[1]Brown University Pawtuxet River Study Project, National Science Foundation, Student-oriented Studies Project. 1972.

Pollution is by far the most serious limiting factor affecting the lower Pawtuxet fishery. Heavy pollution has made the main stem almost completely uninhabitable for fish. Pollution has also adversely affected the lower portions of the North and South Branches. Prior to [illegible] enactment of the Federal Water Pollution Control Act, [illegible], the primary water pollution contributors, were untreated [illegible] chemical manufacturing plants, textile mills and many similar industrial complexes. Low flows, sewage and domestic waste disposal systems also contributed substantially to water quality degradation. Since implementation of the Federal Water Pollution Control Act Amendments of 1972, the Pawtuxet River has been receiving smaller amounts of industrial pollutants as industries treat or tie into the watershed's [illegible] municipal secondary treatment facilities. Non-point discharges and low flows will be the major limiting factors hindering the river's recovery. The out-of-basin transfers of water, 7? million gallons per day from Scituate Reservoir and 26 million gallons per day from the proposed [illegible] River Reservoir, coupled with very low releases from Flat River Reservoir on weekends, indicate that, in the foreseeable future, the volume of waste water in the watershed will increase, while the streamflow from upland drainage sub-basin will decrease.

From River Point eastward the Pawtuxet currently supports approximately 500 man-days of fishing. Children from local [illegible] undaunted by the river's present condition are res[illegible] majority of this fishing pressure.

With pollution reduction and adequate stream flow the lower 11.? miles of the Pawtuxet could support a warm-water fishery based upon [illegible] bass, northern pike and chain pickerel. The potential of this fishery based on population of 100 lbs. of fish/acre and a 40% harvest of one pound of fish/day, exceeds 5,400 man-days of fishing per year. With extensive access and a return of anadromous species to the lower river fishery could be expanded manyfold.

Wildlife Resources

The Pawtuxet watershed supports an important segment of the wildlife species found in Rhode Island. Cottontail rabbit, pheasant, ruffed grouse, quail, gray squirrel, woodcock and mourning dove are generally distributed throughout a major portion of the basin, including some of the more heavily urbanized towns of the lower watershed. The pheasant population is supported by stocking of good habitat units in areas open to hunting. The western and central portion of the watershed is heavily forested, providing habitat for deer. They are found in good numbers throughout this area of the watershed. Urban and residential development in the eastern third of the watershed limit white-tailed deer populations.

Other wildlife species within the basin include mink, muskrat, skunk, fox, raccoon and otter. These species do not contribute significantly to consumptive use within the watershed, but do serve as the focus of much non-comsumptive wildlife enjoyment. A few of the species such as mink and muskrat do provide a little income for those who trap during the fall and winter open season.

There are many important waterfowl habitat sites within the watershed. Their importance stems from the amount of present use they receive and/or because of their management potential for waterfowl feeding, resting or nesting.

In 1972, the U.S. Fish and Wildlife Service made a reconnaissance of the Pawtuxet River Basin for the purpose of delineating major wetland areas which should be managed and/or preserved to best meet multipurpose needs. During this survey, several areas were identified as having habitat of high wildlife use which should receive priority for protection or management of waterfowl and other wildlife.

Within the Pawtuxet Watershed, approximately 36 wetlands totaling 1,500 acres were found to have high value for waterfowl and other wildlife. The largest wetland lies along Mishnock Brook in Coventry and West Greenwich and totals about 500 acres. Another unit of about 30 acres lies along the Pocasset in Cranston and a third unit along Nooseneck River (cedar swamp) in West Greenwich. There are other equally important, though smaller wetlands located along the main stem and in the tributary system that also poses signficant wildlife potential. To date, very little has been done within the watershed to increase waterfowl populations, except for the creation of wood duck nesting boxes. There are but three publicly-owned areas in the basin protecting wetlands. The Ponagansett Public Fishing Area in Foster encompasses 23 acres of wetland, Snake Den State Park contains 38 acres, and the Big River Reservoir area encompasses 600 acres of valuable wetland. If the Water Resources Board's planned dams are constructed at Snake Den and Big River, however, all or most of these areas will be inundated and their value to wildlife lost.

In the area of Apponaug Cove shallow water areas and mud flats are frequented by black duck, mallard, Canada goose, bufflehead, scaup, snowy egret, mute swan, great blue heron, gulls and terns. The shoreline is bordered by a Spartina alterniflora marsh. There is no question that the marsh lands contribute detritus and invertebrate organisms that enter the biological food chain with the end result of Greenwich Bay being one of the most productive shellfishing and sport fishing spots of the State.

The State of Rhode Island is extremely interested in preserving wetland areas. The State has acknowledged the value of inland wetland areas by enacting legislation for their protection. The "Fresh Water Wetland Act", approved July 1971, prohibits individuals, companies, state or local governments from disturbing or destroying inland wetlands [illegible] a permit from the Department of Natural Resources. A recent [illegible] sive Study of the Southeastern New England Area, conducted by the [illegible] England River Basin Commission, also recognized the value and importance of inland wetlands. Major recommendations of the study included protection of wetlands and floodplain areas.

The Rhode Island Division of Fish and Wildlife places high priority on purchase of land suitable for inland game bird and waterfowl hunting since it is in short supply. Priority is also placed on acquisition of land or easements along streams and water bodies, and of pond [illegible] and/or flowage rights in areas allowing fishing. The need for preservation and management of wetland areas and development of streambank access should be an important consideration in any coordinated program for water use. In the lower basin, especially Warwick where flood problems are prevalent, the [illegible] character of the basin [illegible] hunting and pollution makes the main stem presently [illegible] fisheries. Preservation of wetland areas and development [illegible] considerations, however, due primarily to the [illegible] river, its floodplain, and wetlands to this urban [illegible] of the river and its semi-natural open space [illegible] industrial, commercial, and residential developments [illegible] ideal and unique area for nature walks, wildlife photography, and [illegible] watching. As pollution of the Pawtuxet River is decreased and its potential for supporting resident and anadromous fisheries [illegible], the area will be in need of public access. Any plan for the watershed should avoid degradation of the area's present recreational, aesthetic and wildlife capabilities and provide for access to the river due to its potential fisheries capabilities.

Urbanization of the lower watershed with its attendant suburban areas, highways, dredging and filling of wetlands, shopping plazas, and industrial developments are major challenges to efforts to conserve and enhance fish and wildlife in this area.

Coincident with habitat destruction, urbanization has also led to land closure and access problems. Posting of private lands is becoming increasingly common within the watershed. Prohibiting public access restricts utilization of the wildlife resource. An intensive public relations program would perhaps help in opening private lands to public use but the only lasting solution would appear to be in placing key segments of wetlands, uplands, and streambank in public ownership. The

state's "Fresh Water Wetland Act" and local community zoning restrictions can be effective in preserving important wildlife units but does not insure that these lands will be retained as areas open to public access.

The impacts on fish and wildlife would vary depending on the ten different alternatives. Those alternatives which include the Natick Diversion have the potential to adversely affect marine life in Apponaug Cove if freshwater from the tunnel is mixed with the salt water of the cove. Those alternatives including the Warwick Ave Local Protection Project (LPP) would not have a significant effect upon existing fisheries due to the existing poor water quality. The Warwick LPP, which would eliminate a meander of the river, would reduce the amount of streambank available to fishermen assuming pollution reduction and fisheries restoration. Important wildlife habitat will be lost due to the channel realignment. In addition, approximately 7 acres of the Pawtuxet Reservation and one acre of the natural stream channel may be added to the lands occupying the Warwick Industrial Park. Implementation of flood control storage at the Big River Reservoir could adversely impact wildlife in the area if and when flood storage activities took place.

APPENDIX 6

SOCIAL & CULTURAL

RESOURCES

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SOCIAL IMPACT ANALYSIS

The social impacts of the alternative structural schemes for flood protection along the Pawtuxet River will be discussed in three parts. First, the short-term impacts related to construction, second, the long-term impacts of the facilities and of protection, and third, the impacts of "no action."

Short-Term Impacts:

Since construction time is estimated at 2-4 years, "short-term" impacts associated with construction require full consideration.

For two local protection projects abutting industrial areas, (Warwick Industrial Park and Bulova), the impact of construction on traffic is an important consideration. Although both projects are close to major highways, the Warwick Industrial Park project, including Geigy Chemical, straddles a main local traffic artery between Warwick and Cranston. Additional traffic control and other safety measures may need to be implemented in this area.

Two elements have been suggested for providing flood control protection for the Norwood area; Norwood Local Protection, and the Norwood Land Bank. Both the construction and post-construction phases of the Norwood Local Protection project will have significant impacts on the neighborhood. Because the construction site is located in a residential area with limited road access, the short term impacts related to truck traffic and air and noise pollution are significant. The presence of heavy truck traffic over an extended period of time will create a safety hazard for all neighborhood residents. Local roads in this neighborhood are limited in their capability to handle extensive use by this kind of traffic. To minimize these effects careful consideration of the selection of access routes, temporary easements, and general planning of traffic routes will be given.

The Natick diversion project itself involves 2 sets of construction impacts related to the intake site and the outlet site. At the intake site, the impacts to be measured ar primarily noise (how much blasting will be done, how close to homes, businesses or recreation areas) and traffic. At the outlet site, these impacts must also be measured with additional attention to possible disruption of recreation and marina industry in Apponaug Cove during construction.

Long-Term Impacts:

The long-term project impacts on pollution in the area are closely related to the effects on land use. Over the past 20 years, Warwick has

developed rapidly as a residential, commercial and industrial center as population and jobs moved south out of Providence. This development is in part attributed to the Interstate Highway System paralleling the river and within its flood plain. To the extent that local protection projects make new land available for development, this trend may continue, further encouraging the location of commerce and industry in Warwick.

The local protection project for the Warwick Industrial Park will create new land for industry. However, since the pattern of population movement is already established, it is difficult to gauge the additional contribution of the project to this pattern. It is also not known whether the Warwick Industrial Park development would provide jobs for a local or an area-wide labor force. In the latter case, the location of jobs would affect the settlement of people moving to the area for employment and their commuting patterns.

Protection of Norwood would make additional land available for housing, encouraging new growth in an older area. The combination of new homes and greater protection would increase land and real estate values. Higher values may mean higher taxes and in those few cases where people rent homes or flats, higher rents. This could result in forced relocation for residents unable to afford these costs and therefore bring about changes in the structure of the neighborhood, the [illegible] desired by its residents, etc. Whether these increases in taxes and rents are outweighed by the reduction in annual losses warrants further study.

In addition, the Norwood project itself would displace 6-10 families whose homes are located in the path of the proposed dike. The number of homes involved, the characteristics of the displaced population and the plans for relocation must be known to determine the significance of this impact. However, displacement is always an issue requiring serious consideration.

Housing might also be affected in the future in the section of Cranston opposite Norwood if the combination of protection on the Norwood side and increasing river heights increases flood frequency in this area. This possibility depends on land elevations and related technical data and will be investigated. The appearance of the dike itself is unlikely to affect real estate values on the Cranston side or otherwise impact the neighborhood.

Another set of long-term consequences involves recreation and recreation-related industries. The presence of dikes and walls at the local protection sites means there will be no direct access to the river at these locations unless it is provided for in the final design. For example, steps leading over the dikes could be provided leading to the

thirty foot buffer zone and walkways along the river. Currently, the land along the river is privately owned and there is theoretically no access to the river. Therefore, future recreational development of the river banks in these areas does not have to be ruled out. The appearance of the projects from across the river will determine their effect on passive recreation in the surrounding area. This effect is expected to be minimal since the proposal calls primarily for earth dikes, except in the industrial areas which are not available for recreation in any case. The addition of a dam below the diversion and the permanent inlet structure will rule out recreational development in that section of the river. As there is already an existing dam 200 feet upstream of the proposed concrete dam, recreational opportunities in this area are already limited. Since the towns have undertaken a study of possible recreational sites along the river, it should be possible to determine whether any conflicts exist between community recreation plans and the project alternatives.

One other area of social importance must be considered. At present there are no plans to protect the sewage treatment plant sludge disposal fields at West Warwick. During flooding, material from these fields may be swept into the river, creating health and pollution problems downstream.

If West Warwick were to install sludge digestors the sludge currently placed along the river will contain significantly less pollutants. Thus when natural flooding occurs the pollutional load downstream will be less. If the diversion is constructed, flood flows will be almost eliminated on this area.

The other protection for the Norwood area is identified as the Norwood Land Bank. Its construction and post construction implications on the local area are more extensive than those for the local protection element. Implementation of the Norwood Land Bank scheme requires the displacement of 30-35 families from this area. In some cases relocation of the present structure to another site could be accomplished; whereas in other cases new homes could be purchased by displaced residents. The stress associated with loss of home could be significant in this neighborhood characterized by a rather stable, blue-collar population. Removal of structures would occur over several years, with completion contingent on construction of Big River Reservoir. Again construction phase activities (closer to destruction) would be quite extensive causing significant traffic and air and noise pollution effects.

Impacts site specific to the addition of flood control storage in Big River Reservoir are indeterminable at this stage of study. Another ongoing study is already in the process of assessing the impacts related to water supply provisions. It is anticipated that providing extra

storage capability would not have any significant effects beyond these experienced with provision of the water supply capability along.

The provision of flood control protection along the mainstem of the Pawtuxet has significant land use implications. By decreasing the flood plain, new land becomes available for development, which previously would have subject to NFIP regulations.

Finally, the diversion tunnel may affect population movement if it has any consequences for the stability of the buildings, roads and lands located on the surface. Both homes and institutions are located on the surface area and any possible effects on these structures must be studied. Furthermore, easements will be needed for these properties.

No Project:

This alternative, "do nothing", must be considered in stages, because certain options on the basic plan can be eliminated without cancelling the project altogether.

Option 1: No local protection for Norwood. This option involves two social considerations. First, the completion of the Warwick Industrial Park project which offers a high level of protection to industrial and residential property in one flood prone area and not in another raises the issue of equity. Is it politically and socially acceptable to fully protect only one flood-prone area? The same issue arises in a more acute form if the local protection is provided for Norwood -- all residential in character -- while an additional local protection project is proposed for another industrial location -- Bulova.

Second, failure to protect a residential area often results in deterioration of the housing in that area. Essentially, this is what has been happening in the Norwood area. Since the flood-prone sections of Norwood include many older homes, the possbility of further deterioration must be considered if this area is unprotected. This is an important issue in a city which has little adequate low cost family housing. In addition, no new housing can be built in the area without protection.

Option 2 - No diversion. In this case, only the industrial local protection projects are built. The heights of the dikes and walls are increased, creating issues of aesthetics, and the possibility of future flood damages outside the protected area is increased.

Option 3 - No project. If "nothing" is done the potential of future flood damages is increased as in Options 1 and 2. In addition, development of vacant lands in the industrial park is restricted and restrictions on new housing continue to apply in the Norwood area. Beyond that, additional flood problems are also likely to develop in flood-prone areas of West Warwick.

Cultural Resources

Discussion with the Rhode Island Historic Preservation Commission in 1976-77 determined that an underwater archaeological reconnaissance in Apponaug Cove was needed in connection with the Natick Diversion Alternative. The Elmwood Avenue landbank and Warwick Avenue Industrial park are unlikely to contain significant cultural resources, due to intensive modern residential and industrial development. As the Natick Diversion alternative has been dropped from consideration, no effect is anticipated upon significant cultural resources within the Cranston-Warwick portion of the project.

Archaeological and historic resource reconnaissance studies of the Big River Reservoir were conducted in 1978 in association with feasibility stage planning for that project. These studies have identified 5 prehistoric archaeological sites and 25 historic sites and structures below the proposed water supply pool level of 302.5 msl. Impacts due to flood storage at 2.5 feet do not appear to significantly contribute to total impact of the Big River Reservoir project. Further location, identification, and assessment of cultural resources within Big River will proceed during future planning stages. Coordination with the Rhode Island Historic Preservation Commission will continue for both the Pawtuxet River and Big River studies.

APPENDIX 7

ECONOMICS OF SELECTED PLAN

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ECONOMICS OF THE SELECTED PLAN

The economic criteria and preliminary economic evaluation applied in formulating the selected plan were discussed in Appendix 2. As a follow-up to this basic criteria, this section presents an in-depth economic analysis of the structural and non-structural features of the selected plan namely, Big River Reservoir; the Warwick Local Protection Project and the Norwood Land Bank. Included in this analysis are a total first cost and project investment; annual charges consisting of interest, amortization, operation and maintenance, major replacements and the loss of taxes on lands; and all benefits allowable under ER 1105-2-351, entitled "Evaluation of Beneficial Contributions to Natural Economic Development for Flood Plain Management Plans." Also an ER 1105-2-353 analysis has been performed on the benefits for the Norwood Land Bank.

COSTS AND CHARGES

FIRST COSTS AND PROJECT INVESTMENT

Detailed estimates of construction costs and costs for lands and damages of the selected plan are summarized in Tables 7-1 thru 7-3. Applied unit prices for the Warwick Avenue Industrial Park reflect December 1977 price levels updated to June 1978 costs. The unit prices for Big River Reservoir were based upon a preliminary feasibility study performed in 1974 by a architectural engineering firm who originally designed the majority of this proposed reservoir[1]. These costs have been updated to June 1978 levels using ENR cost indexes. These are preliminary costs only and used for planning purposes only. The current costs are currently under evaluation by this office and presented in other sections of the Big River Report. Lands and damages at Warwick as well as relocations were included in the original estimate from Table 7-2. The preliminary cost allocation of $452,000 for flood control at Big River Reservoir is shown in Table 7-1. The preliminary cost estimate for the Norwood Land Bank is shown on Table 7-3. Because of a recent detailed real estate evaluation of all Norwood properties these annual charges reflect May 1980 levels.

ANNUAL CHARGES - See Below

Annual Charge Summary
6-7/8% - Dec. 78 P.L.

Option 1	Big River Separable F. C. Charges[1]	452,000
	Warwick Avenue LPP	865,000
	Norwood Land Bank*	112,300
		1,429,300
Option 2	Warwick Avenue LPP	865,000
	Norwood Land Bank*	152,000
		1,017,000

*Excludes uniform relocation assistance; May 1980 Price Levels

[1] Based on the Big River feasiblity report currently being prepared by the Corps of Engineers, NED, these cost have been reduced.

TABLE 7-1

SINGLE PURPOSE FLOOD CONTROL RESERVOIR
AT BIG RIVER RESERVOIR SITE
COST ESTIMATE

	Quantity	Unit Cost	Total Cost
Preparation of Site	-	-	1,550,000
Stream Control	-	-	407,000
Earth X-Common	82,000 CY	2.40	196,800
Earth X-Borrow	200,000 CY	2.20	440,000
Impervious Blanket	90,630 CY	3.20	290,000
Rock X-Open Cut	40,000 CY	10.00	400,000
Embankment (Rolled)	232,000 CY	0.90	208,800
Select Gravel	22,000 CY	8.20	180,000
Rockfill Placing	50,000 CY	2.70	135,000
Concrete, Mass.	7,600 CY	130.00	988,000
Concrete, Reinf.	4,200 CY	190.00	798,000
Bridge Superstructure	1,260 SF	40.00	50,400
Gates and Machinery	-	-	26,000
Stoplogs	320 SF	60.00	19,200
Misc. Items 10% ±			350,000
Cemetery Relocations	45 Graves	1,200.00	54,000
Road Relocations	13,000 lf	166.00	2,158,000
Utility Relocations	26,000 lf	30.00	780,000
Contingencies 20% ±			1,730,000
Buildings, Grounds & Utilities			130,000
E&D - 12%			1,292,000
S&A - 15%			1,615,000
Lands and Damages			3,626,000

TOTAL COSTS -	$17,398,000
2 yrs. x 1/2 x .06125	1,065,630
Construction Cost	$18,463,630
Interest (.06125)	1,130,000
Amortization (.0001086)	2,010
ANNUAL CHARGE	$ 1,132,910

Using Preliminary Scrub Method

TOTAL CONSTRUCTION COSTS	$ 3,930,000
ANNUAL COST	$ 452,000

TABLE 7-2

PROJECT COST OF STRUCTURAL ELEMENT OF THE SELECTED PLAN

WARWICK AVENUE LOCAL PROTECTION

Items	Estimated Quantities	Unit	Unit Cost	Total Costs
CONSTRUCTION COSTS				
Preparation of Site	1	Job	L.S.	30,000
Control and Diversion of River	1	Job	L.S.	110,000
Common Excavation	139,500	c.y.	4.70	656,000
24" Protection Stone	22,000	c.y.	35.00	770,000
12" Protection Stone	2,200	c.y.	35.00	77,000
Protection Stone (10' wide)	13,900	c.y.	35.00	487,000
12" Bedding Stone	10,800	c.y.	35.00	378,000
Crushed Stone	10,400	c.y.	9.00	94,000
12" Gravel Bedding	17,500	c.y.	9.00	158,000
Comp. Gravel Fill	14,500	c.y.	8.00	116,000
Comp. Impervious Fill	33,400	c.y.	6.00	200,000
Comp. Random Fill	25,100	c.y.	4.70	118,000
Comp. Sand Fill	6,900	c.y.	6.00	41,000
Comp. Pervious Fill	39,000	c.y.	6.00	234,000
Topsoil	1,300	c.y.	8.00	10,000
Seeding	7,800	s.y.	0.60	5,000
Bituminous Pavement	1,100	s.y.	4.00	4,000
Concrete T Walls	5,400	c.y.	140.00	756,000
Concrete L Walls	1,700	c.y.	140.00	238,000
Concrete I Walls	250	c.y.	140.00	35,000
Concrete Gravity Walls	650	c.y.	100.00	65,000
Stoplog Barrier @ Warwick Avenue	1	Job	L.S.	15,000
Concrete-Pedestrian Gate	140	c.y.	140.00	20,000
Concrete-Railroad Gate	300	c.y.	140.00	42,000
Cement	47,700	cwt	3.00	143,000
Reinforcing Steel	1,170,000	lb.	0.50	585,000
Structural Steel - Pedestrian Gate	5,900	lb.	3.50	21,000
Structural Steel - Railroad Gate	17,400	lb.	3.50	61,000
Steel Sheet Piling	8,200	S.F.	9.50	78,000
8" BCCMP (Sub-drain)	3,600	L.F.	6.00	22,000
Interior Drainage	1	Job	L.S.	378,000
Pumping Stations	2	Job	L.S.	1,002,000

Sub-Total	=	6,949,000		
Contingencies (20%)	=	1,390,000		
Sub-Total	=	8,339,000		
Engineering & Design (14.5%)	=	1,209,000		
Supervision & Administration (9.0%)	=	750,000		
TOTAL CONSTRUCTION COSTS	=	10,298,000	=	$ 10,298,000
COSTS FOR LANDS AND DAMAGES				
Lands and Improvements (Fee/ Permanent Easement)	=	38,000		
Temporary Construction Easements	=	48,000		
Severance Damages	=	0		
Relocation Assistance Costs	=	2,400		
Acquisition Costs	=	24,000		
Contingencies	=	32,500		
		194,900		
TOTAL LANDS AND DAMAGES COSTS (ROUNDED)	=	200,000	=	200,000
TOTAL PROJECT FIRST COST				$ 10,498,000
TOTAL PROJECT FIRST COST (UPDATED TO SEPT. 1978)				$ 11,170,000
INTEREST DURING CONSTRUCTION				1,152,000
TOTAL CONSTRUCTION COST				12,322,000
INTEREST (AMORTIZATION .06884)				848,250
OPERATION AND MAINTENANCE				15,000
				863,250
		(Rounded to)		865,000

TABLE 7-3

PRELIMINARY ESTIMATE OF REAL ESTATE COSTS
NORWOOD LAND BANK
MAY 1980 PRICE LEVELS
7-1/8% Interest Rate

Land and Improvements	
54 Improved Properties	$1,350,000
Contingency (20% of above)	270,000
	$1,620,000
Relocation Assistance Costs	
36 Owner Occupied Units @ $15,000	540,000
18 Tenant Occupied units @ $4,000	72,000
Acquisition Costs	
54 Private Ownerships @ $3,000	162,000
	$2,394,000
Rounded -	$2,400,000
Option 1 - With Big River Reservoir	
Costs for 40 Homes	$1,780,000
Annual Charge Without Relocation Assistance	126,800
Option 2 - Without Big River Reservoir	
Costs for all 54 Homes	$2,400,000
Annual Charge Without Relocation Assistance	152,000

BENEFITS

BASIC BENEFITS

The benefit analysis will consist of the South Branch of the Pawtuxet (Zones 2A-1 and 2A-2) and on the main stem Pawtuxet River, Zones 3 through 8. With the area experiencing a rapid growth throughout the basin, flood discharge frequencies, as explained in Appendices 1 and 4, are expected to increase 10 percent between the initiation of the study (1972) and 1990 and another 10 percent between 1990 and 2020. All damages and benefits, updated to June 1978 price levels, reflect the level of development present in the watershed for mid-1972.

The key elements of the selected plan are Big River Reservoir, the Warwick Avenue local protection works, and the Norwood Land Bank. These first two flood control measures are the only structurally oriented corrective measures that are acceptable to local interests, economically justified on an incremental basis and satisfy some of the local flood control needs of the basin. Big River Reservoir would be a multi-purpose reservoir located along a tributary stream (Big River) of the South Branch of the Pawtuxet River. By increasing the height of this proposed water supply dam at Big River by a small increment, currently estimated at 3.0 feet, additional flood protection to downstream areas would be provided. The increased height would provide about 9,500 acre-feet of flood control storage, equivalent to about 6 inches of runoff from a drainage area of 29.7 square miles.

The Warwick Avenue local protection project consists of a system of walls, dikes and appurtentant facilities that provides limited regional flood protection to the area known locally as the Warwick Industrial Park, establishments along Warwick Avenue in Warwick and the portions of the Ciba Geigy plant in Warwick. A complete description can be found in Appendix 4.

The Norwood Land Bank consists of the outright purchase of 40 to 54 homes in the Norwood peninsula also locally known as the Belmont section of Warwick. These homes are all highly flood-prone from events more frequent than a storm with a 8% recurrence interval. They have been flooded several times in the past 10 years, several receiving first floor flooding.

Flood damage reduction benefits which accrue to the reservoir are the difference between flood damages without the project in each reach of the river to be affected and those remaining with the project in operation.

For the local protection project, benefits were measured as the residual losses after reductions in flood flows by the reservoir for all ranges of floods up to the Standard Project Flood.

As stated in Appendix 1, indications are that a flood of an estimated 20 year frequency would have caused recurring losses in excess of $1,500,000 in zones 4 through 8 along the main stem, based on damage surveys conducted in 1972-73. Approximately 10 percent of these losses would have been residential, 16 percent commercial and 70 percent industrial, with the remaining 4 percent in the utility, public, highway and erosion categories. Breaking those losses down by community, Warwick and Cranston would each receive about 47 percent of the total losses with the remainder in West Warwick. If a flood of an estimated 50-year frequency had ocurred losses would have risen to over $7,000,000 with 5 percent being residential losses, 17 percent commercial, and 76 percent industrial with the remaining 2 percent in the other categories. Warwick would have sustained 69 percent of the losses, Cranston 29 percent and West Warwick the remainder.

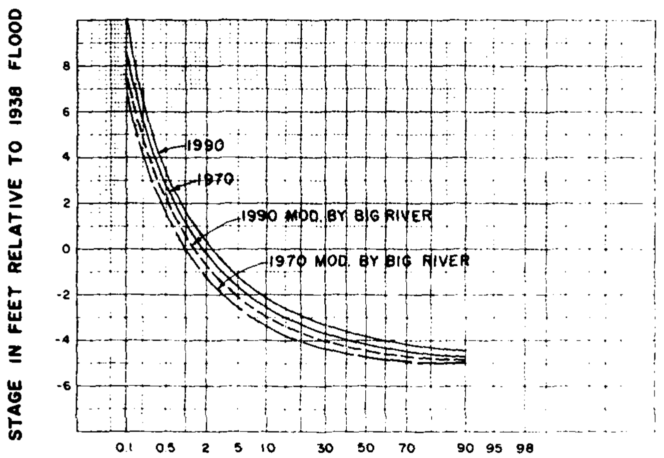
Benefit Estimation

Flood control benefits are defined as flood damages prevented and are based on estimates of potential damages in the flood plain. Flood damage surveys were made which provided dollar estimates of both physical and non-physical losses, by property type, in each zone, related to various stages or elevations of flooding. The result of these surveys are stage damage relationships referenced to specific flooding elevations experienced in a flood of record. The determination of annual damages requires the correlation of hydrological stage frequency data for each damage zone and the stage damage data to produce damage-frequency relationships. Plates 7-1 thru 7-5 show all of the above relationships. Annual benefits are the dollar difference between damages occurring under natural or existing conditions and those that occur with Big River Reservoir and the Warwick LPP in place. Based on current practice in this office it would be at least 1990 before construction of the projects could be reasonably assumed to be completed. Thus 1990 was taken as the base year for benefit analysis.

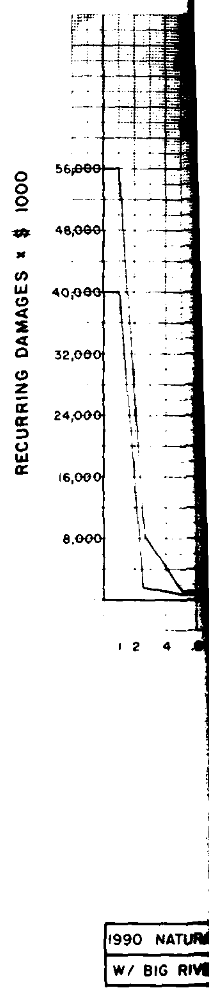
Table 7-4 shows the average annual damages, annual benefits to Big River Reservoir, residual annual benefits to the Warwick local protection project and the annual losses remaining with project implementation in the five impacted zones.

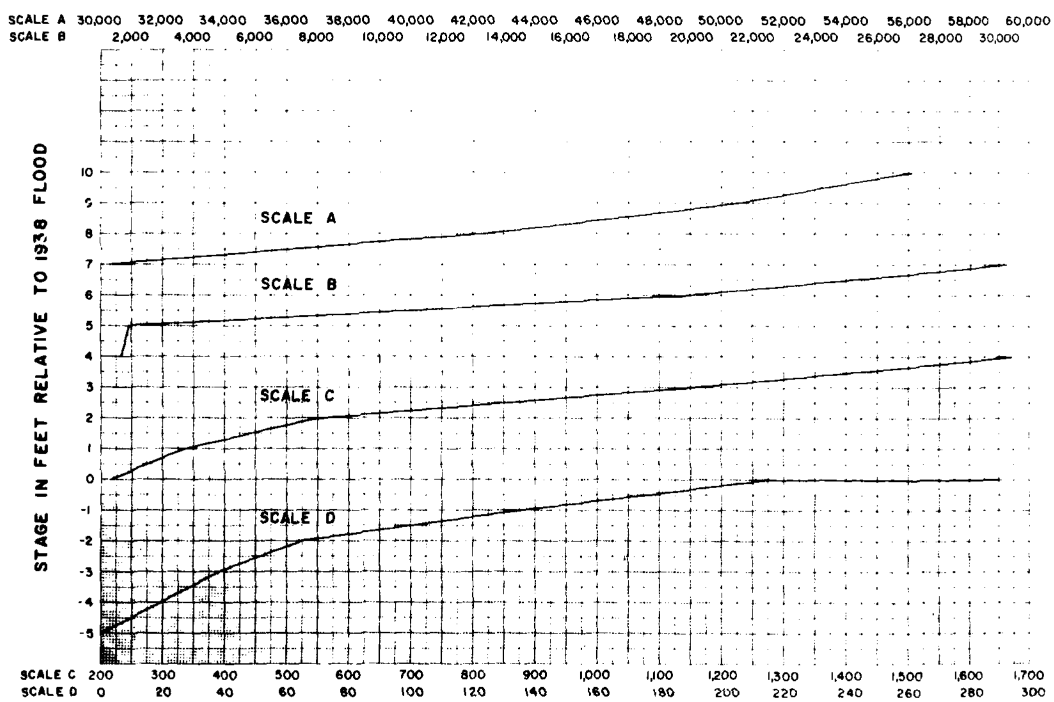
FUTURE GROWTH BEFORE PROJECT COMPLETION (1972-1990)

From the date of the initial damage survey (1972) to the present (1978) numerous new structures have been built in the flood plain, many below the existing hundred year flood level at a greater growth rate than previously discussed in Appendix 1. As these new structures and those expected to be built before project implementation are subject to flood losses, they could

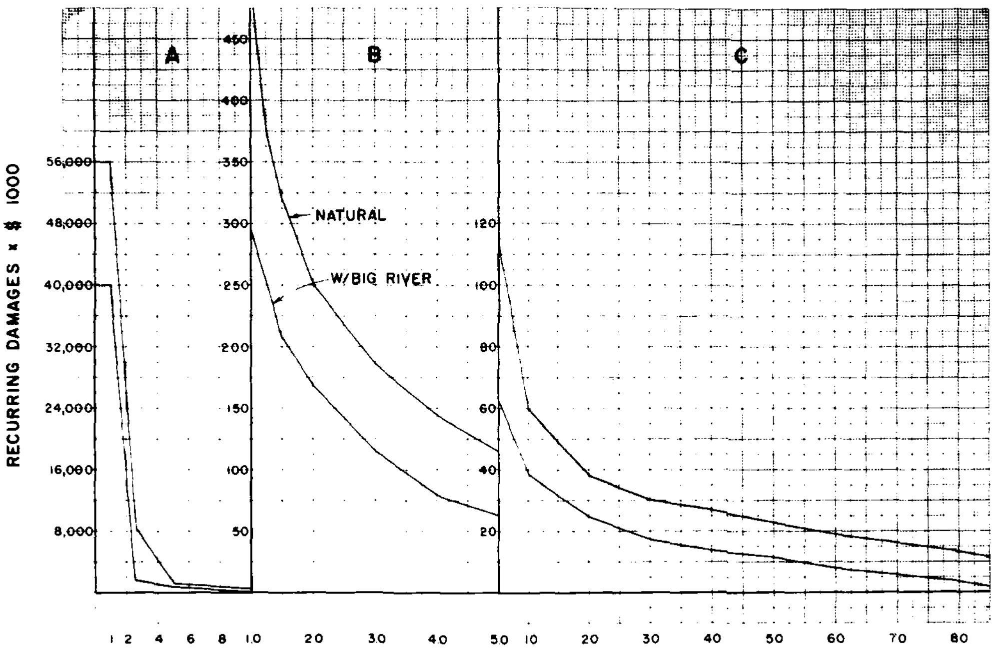


STAGE - FREQUENCY CURVE
NATURAL & MODIFIED





STAGE DAMAGE CURVE
1973 PRICE LEVEL
1973 STUDY ; UPDATED 1978



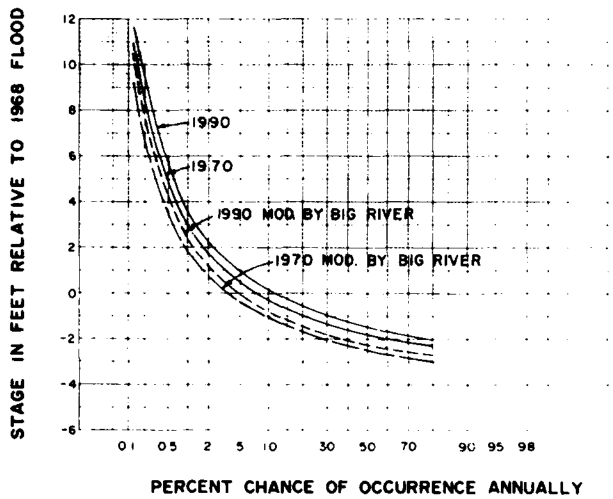
DAMAGE - FREQUENCY CURVE
1972 PRICE LEVEL
1972 STUDY ; UPDATED 1978
1990 HYDROLOGIC CONDITIONS

	RANGE A 1 sq. in. = $32,000			RANGE B 1 sq. in. = $500			RANGE C 1 sq. in. = $2,000			AVERAGE ANNUAL	
	AREA	LOSS	BEN.	AREA	LOSS	BEN.	AREA	LOSS	BEN.	LOSSES	BENEFITS
1990 NATURAL	3.8	121,600		16.9	8450		12.3	33,600		163,650	
W/ BIG RIVER	2.4	76,800	44,800	10.5	5250	3200	6.4	12,800	20,800	94,850	68,800

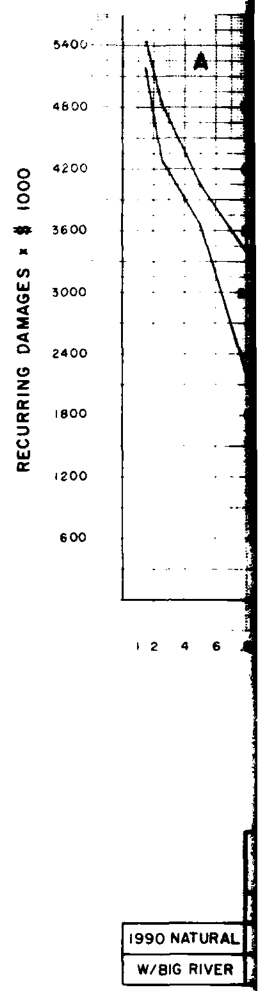
WATER RESOURCES MANAGEMENT REPORT

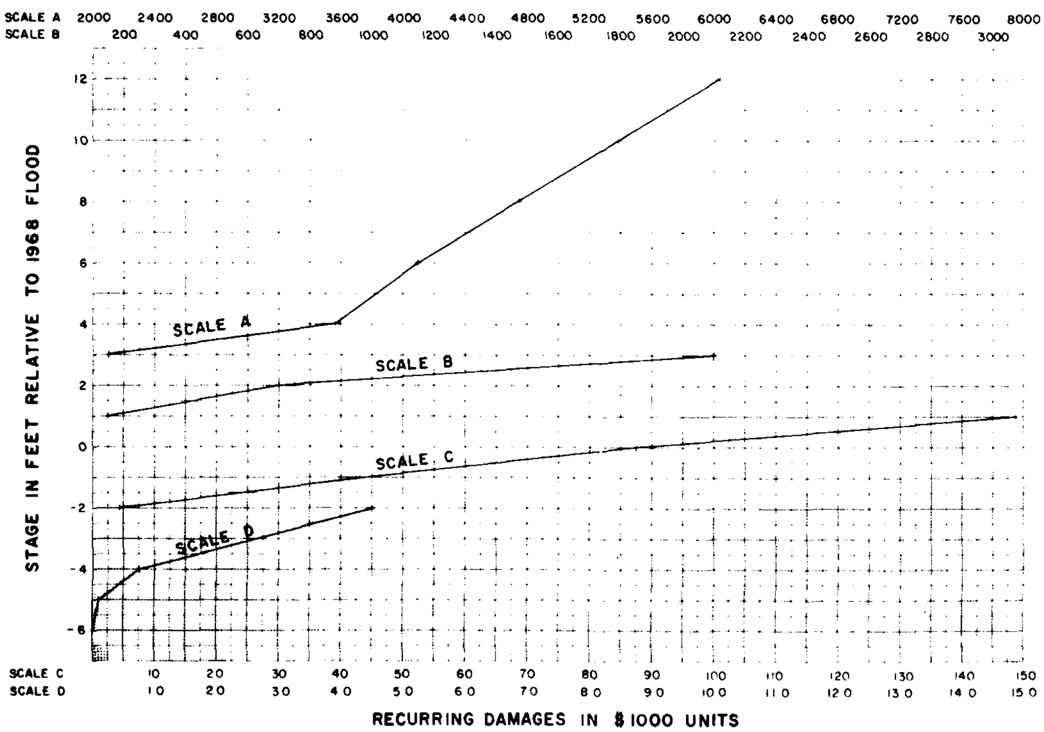
PAWTUXET RIVER BASIN
RHODE ISLAND
DAMAGE-FREQUENCY-STAGE RELATIONSHIPS
BASIC BENEFITS - ZONE # 4

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

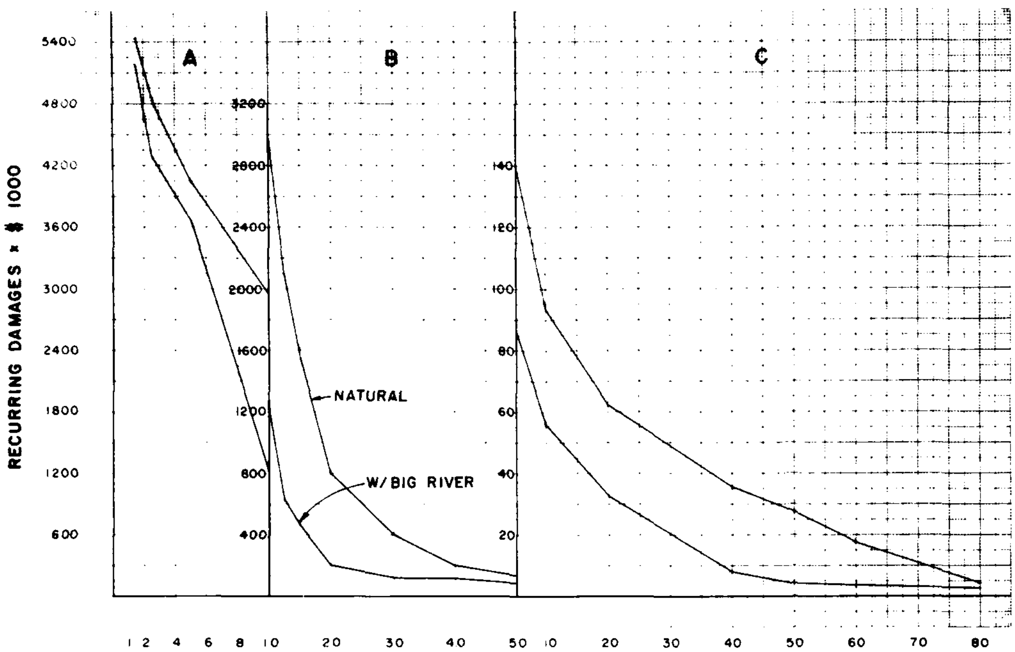


STAGE - FREQUENCY CURVE
NATURAL & MODIFIED





STAGE DAMAGE CURVE
1972 PRICE LEVEL
1972 STUDY ; UPDATED 1978



PERCENT CHANCE OF OCCURRENCE PER SINGLE YEAR

DAMAGE - FREQUENCY CURVE
1972 PRICE LEVEL
1972 STUDY ; UPDATED 1978
1990 HYDROLOGIC CONDITIONS

	RANGE A 1 sq. in. = $2400			RANGE B 1 sq. in. = $4000			RANGE C 1 sq. in. = $2000			AVERAGE ANNUAL	
	AREA	LOSS	BEN	AREA	LOSS	BEN.	AREA	LOSS	BEN.	LOSSES	BENEFITS
1990 NATURAL	17.4	41,760		7.0	28,000		15.4	30,800		100,560	
W/BIG RIVER	14.4	34,560	7,200	2.3	9,200	18,800	6.9	13,800	17,000	57,560	43,000

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN

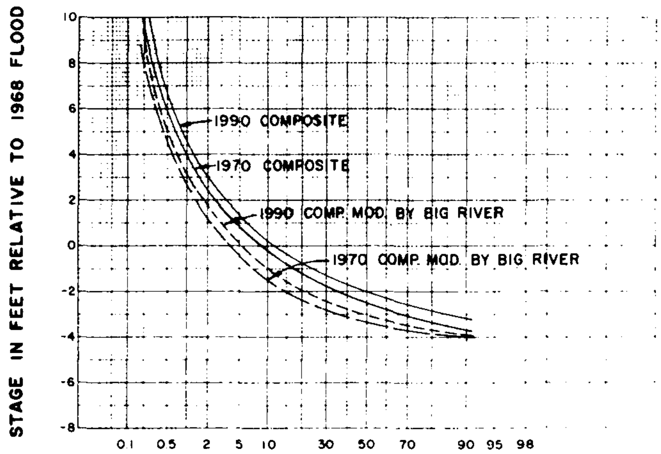
RHODE ISLAND

DAMAGE-FREQUENCY-STAGE RELATIONSHIPS

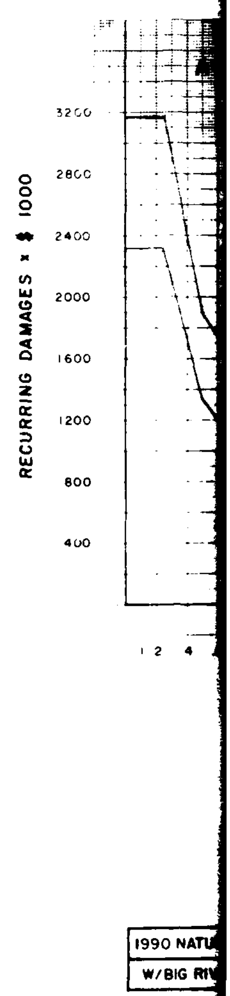
BASIC BENEFITS - ZONE # 5

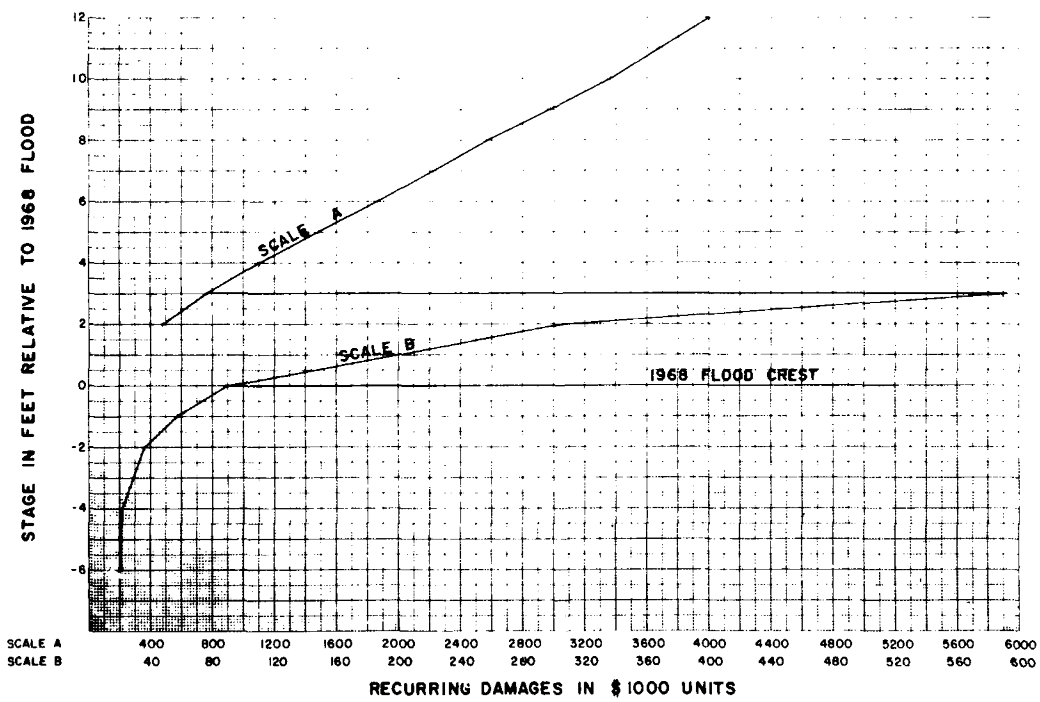
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 7-2

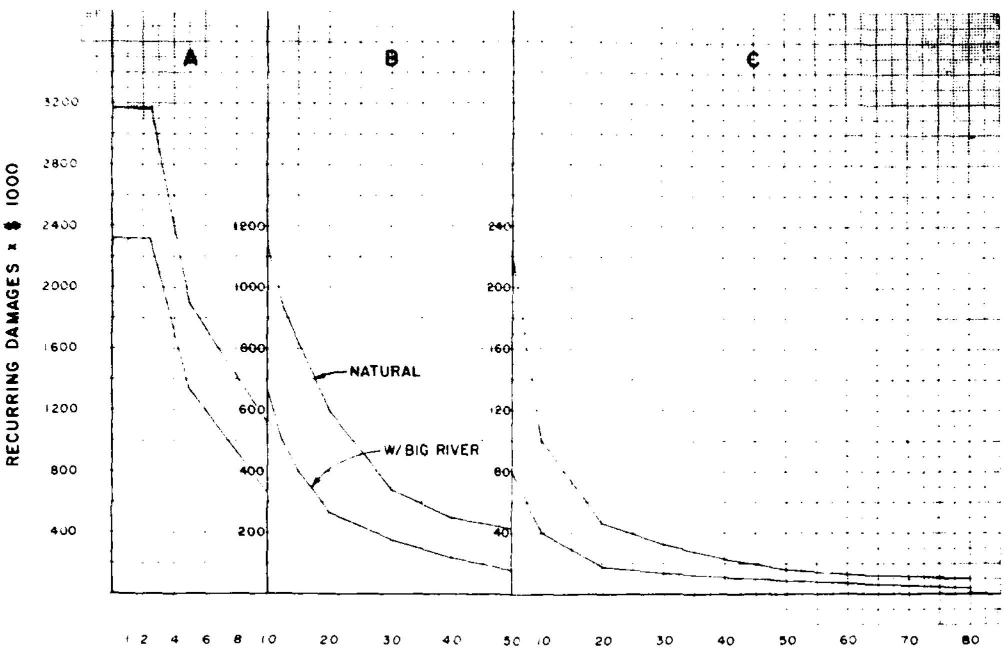


STAGE - FREQUENCY CURVE
NATURAL & MODIFIED





STAGE DAMAGE CURVE
1972 PRICE LEVEL
1972 STUDY ; UPDATED 1978



PERCENT CHANCE OF OCCURRENCE PER SINGLE YEAR

DAMAGE - FREQUENCY CURVE

1972 PRICE LEVEL

1972 STUDY ; UPDATED 1978

1990 HYDROLOGIC CONDITIONS

	RANGE A 1 sq. in. = $1600			RANGE B 1 sq. in. = $2000			RANGE C 1 sq. in. = $4000			AVERAGE ANNUAL	
	AREA	LOSS	BEN	AREA	LOSS	BEN.	AREA	LOSS	BEN	LOSSES	BENEFITS
1990 NATURAL	13.66	21,860		9.12	18,245		6.95	27,800		67,905	
W/BIG RIVER	9.68	15,480	6,380	4.43	8,865	9,380	2.81	11,220	16,580	35,565	32,340

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN

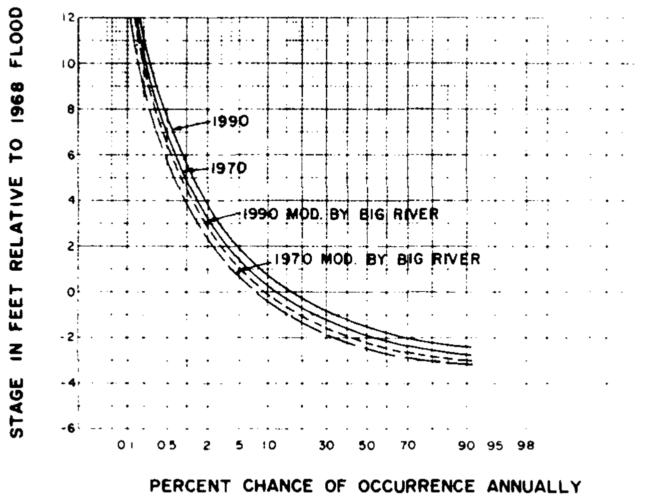
RHODE ISLAND

DAMAGE-FREQUENCY-STAGE RELATIONSHIPS

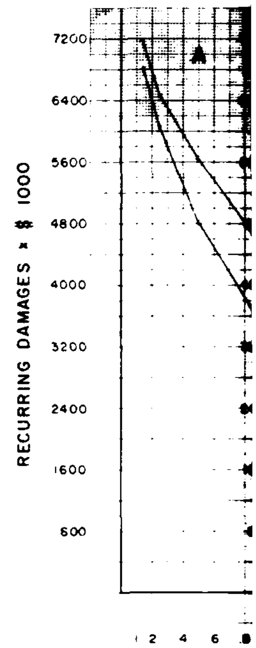
BASIC BENEFITS - **ZONE # 6**

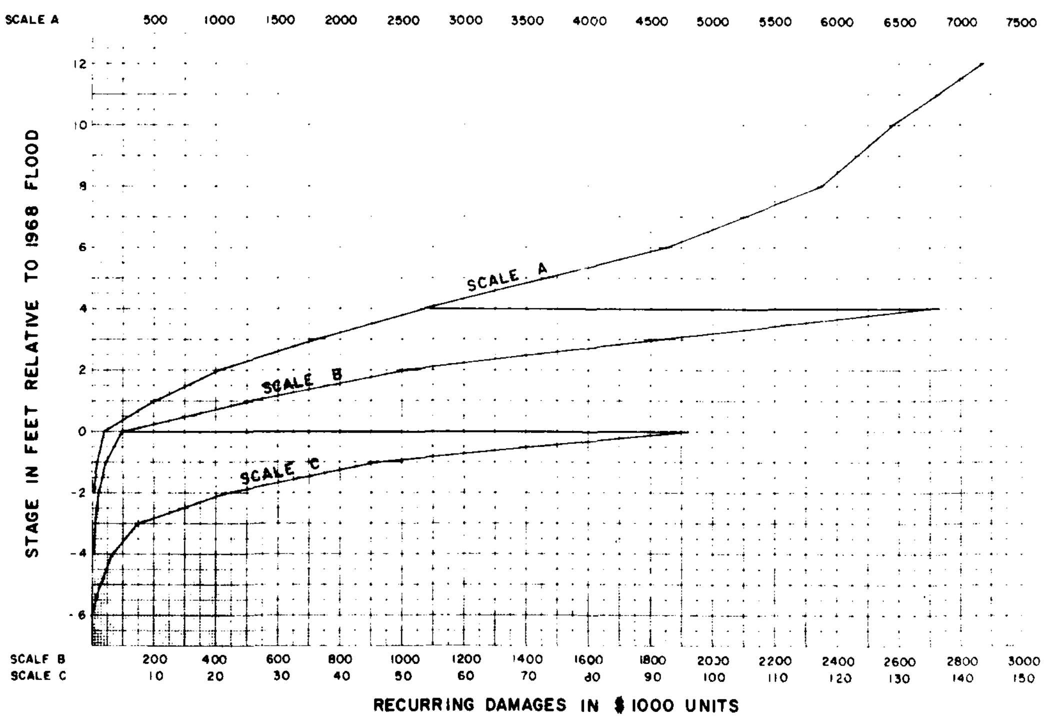
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 7-3



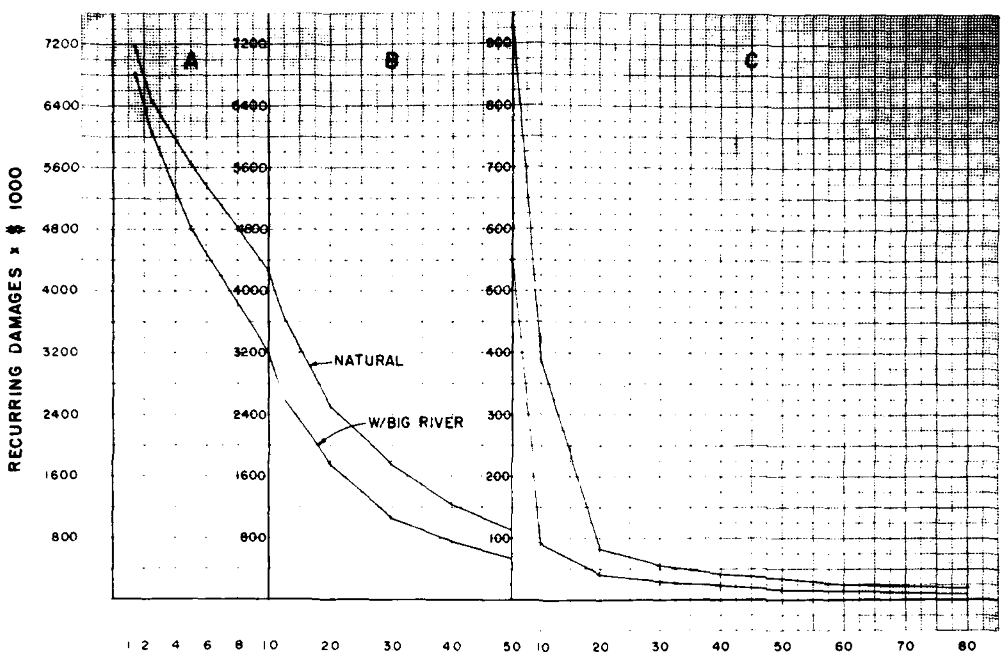
STAGE - FREQUENCY CURVE
NATURAL & MODIFIED





STAGE DAMAGE CURVE
1972 PRICE LEVEL
1972 STUDY ; UPDATED 1978

1990 NATURAL
W/BIG RIVER



PERCENT CHANCE OF OCCURRENCE PER SINGLE YEAR

DAMAGE - FREQUENCY CURVE

1972 PRICE LEVEL

1972 STUDY ; UPDATED 1978

1990 HYDROLOGIC CONDITIONS

	RANGE A 1 sq. in. =$3200			RANGE B 1 sq. in. =$8000			RANGE C 1 sq. in. =$10,000			AVERAGE ANNUAL	
	AREA	LOSS	BEN	AREA	LOSS	BEN.	AREA	LOSS	BEN.	LOSSES	BENEFITS
1990 NATURAL	17.9	57,310		9.73	77,845		7.79	77,930		213,085	
W/BIG RIVER	15.72	50,308	7,005	6.57	52,615	25,230	3.36	33,615	44,315	136,535	76,550

WATER RESOURCES MANAGEMENT REPORT

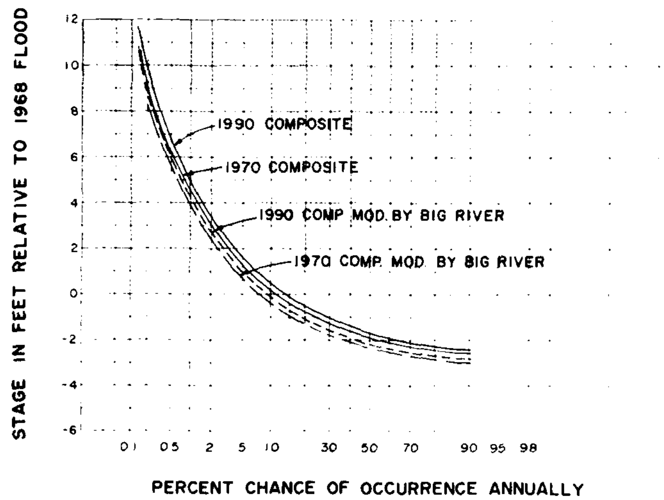
PAWTUXET RIVER BASIN

RHODE ISLAND

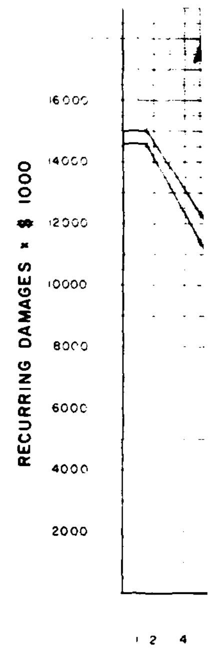
DAMAGE - FREQUENCY - STAGE RELATIONSHIPS

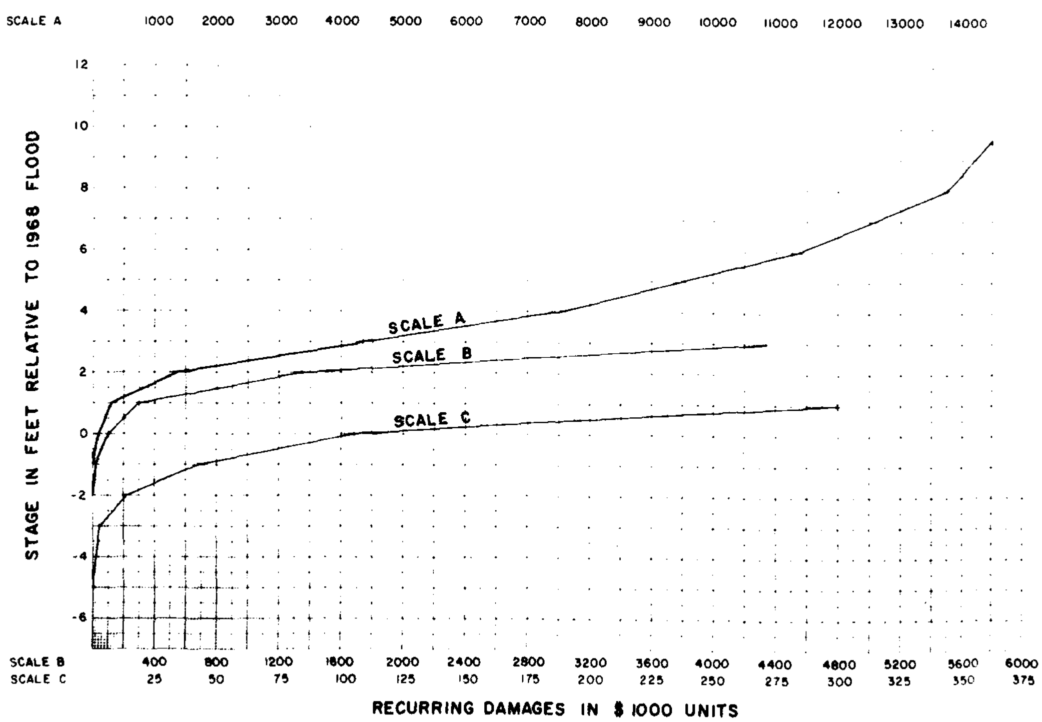
BASIC BENEFITS - ZONE # 7

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.



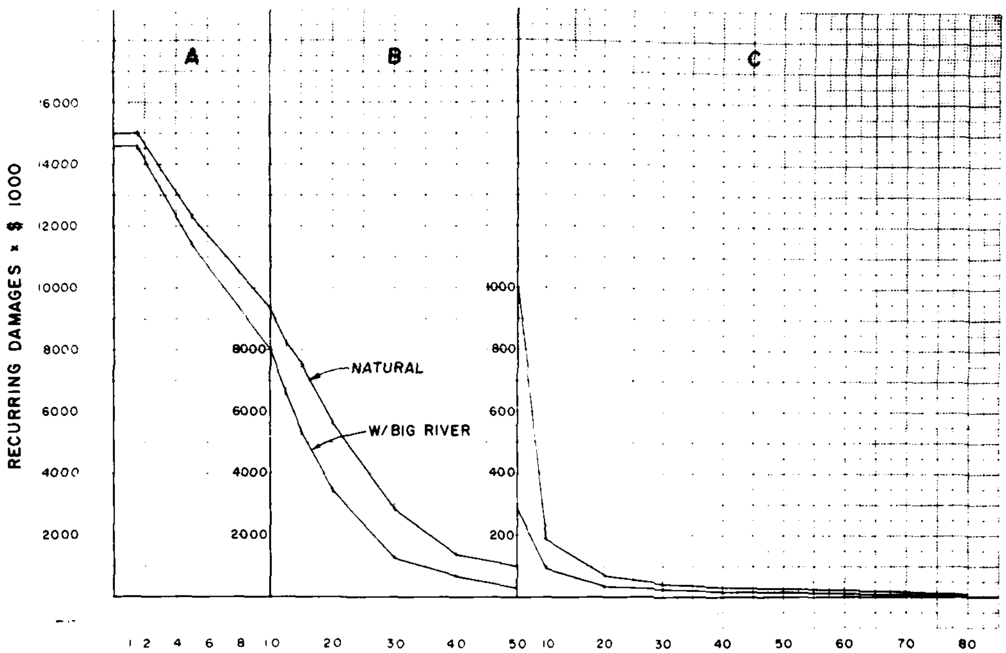
STAGE-FREQUENCY CURVE
NATURAL & MODIFIED





STAGE DAMAGE CURVE
1972 PRICE LEVEL
1972 STUDY; UPDATED 1978

1990 NATU
W/BIG RI
WARWICK
RIGHT B
CRANSTON



PERCENT CHANCE OF OCCURRENCE PER SINGLE YEAR

DAMAGE - FREQUENCY CURVE

1972 PRICE LEVEL
1972 STUDY ; UPDATED 1978
1990 HYDROLOGIC CONDITIONS

	RANGE A 1 sq. in. = $8000			RANGE B 1 sq. in. = $20,000			RANGE C 1 sq. in. = $20,000			AVERAGE ANNUAL	
	AREA	LOSS	BEN	AREA	LOSS	BEN.	AREA	LOSS	BEN.	LOSSES	BENEFITS
1990 NATURAL	15.52	124,165		7.47	149,340		2.88	57,660		331,165	
W/BIG RIVER	14.46	115,715	8,450	4.71	94,315	55,025	1.21	24,220	33,440	234,250	96,915
WARWICK LPP										234,250	
RIGHT BANK	2.44	21,360	91,920	4.52	90,500	90,500	0.88	17,700	21,360	21,360	200,120
CRANSTON, L.B	0.30	2435		0.19	3815		0.22	6520		12,770	

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

DAMAGE-FREQUENCY-STAGE RELATIONSHIPS

BASIC BENEFITS - ZONE # 8

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 7-5

TABLE 7-4

AVERAGE ANNUAL LOSSES AND BENEFITS AS
MODIFIED BY THE SELECTED PLAN
1990 BASE YEAR
JUNE 1978 PRICE LEVEL

Location	Total Annual Damages	Benefits to Big River Reservoir	Residual Losses	New Benefits to Warwick LLP*	Final Residual Losses
SOUTH BRANCH					
Zone 2A-1	500	400	100	-	100
Zone 2A-2	29,000	24,600	4,400	-	4,400
Sub Total	29,500	25,000	4,500	-	4,500
MAINSTEM					
Zone 3	900	450	450	-	450
Zone 4	252,020	105,950	146,070	-	146,070
Zone 5	154,860	66,220	88,640	-	88,640
Zone 6	104,580	49,800	54,780	-	54,780
Zone 7	328,150	117,890	210,260	0	210,260
Zone 8	509,990	149,250	360,740	307,170	53,570
Sub Total	1,350,500	489,560	860,940	307,170	533,770
TOTAL	1,380,000	514,560	865,440	307,170	558,270
Updated to Average 1979 Price Level	1,504,200	560,900	943,300	334,800	608,500

also be afforded a high degree of protection by the selected plan. In accordance with Water Resources Council guidelines projections of future growth in the flood plain must be made assuming provisions of the National Flood Insurance Program will be adhered to. Thus any new growth projected to occur below the 100 year level must be limited to industrial and commercial establishments and must be flood proofed to this level.

The first step in estimating future losses and benefits due to growth in the Pawtuxet River flood plain was to assess present land use and then project future land use demands. As stated in Appendix 1, projections were made for 1990, the proposed project implementation date and the date which corresponded to OBERS projections and for the year 2040.

Projections of demographic and economic activity within the affected area were made independent of any plan for flood control. Indicators used for the projection of growth were population, housing units, and industrial and commercial sector development. These projections were converted to land use demand in the benchmark years utilizing indicator land use ratios derived from historical data. Expressed on an annual rate basis, (acres/year) land use demand in the flood plain of the Pawtuxet River flood plain is as follows.

	1970 - 1990	1990 - 2040
Residential	3.8	4.0
Commercial	5.1	3.1
Industrial	3.0	2.9

These figures are representative of land needed or demanded for development in the flood plain, however, constraints on land supply prevent total absorption. The most important constraint is the National Flood Insurance program. Warwick and Cranston operate under the regular program.

To determine the potential losses expected to result from anticipated growth for industrial, commercial and residential structures from 1972-1990 the following method was employed. For industrial growth, the stage damages for each industrial concern within the Warwick Industrial Park (Warwick Avenue Area) were combined using the 1968 flood stage as a reference point. Most of these establishments did not have water inside the building or above the first floor elevation. (Most do not have basements.) On the average, there were between two and three feet between the first floor and the 1968 flood. A combined stage-damage curve was then prepared. From the damage survey records and a survey of the area, the dimensions of each structure were obtained to determine the square footage of building space and aproximate land area. A unit stage damage curve was then prepared by dividing the damage at each stage height, relative to the

1968 flood, by the combined area of the industrial structures. The final unit stage damage curve for industrial establishments is shown on Plate 7-6 and is based on a 1000 sq. ft. structure. As any new growth that occurs below the 100-year flood level must be floodproofed to that stage, the 100-year flood for the unit stage damage curve was established. On the unit stage damage curve, the +2 elevation was assumed to be equal to the 100-year flood; the elevation at which water would enter the building and begin to cause significant damage.

Similar unit stage-damage curves were prepared for commercial and residential structures. The basis for the data on commercial structures was the stage damage relationships at the Warwick Mall complex (vicinity of northerly bank at river mile 8.5) and the commercial firms at the Warwick Industrial Park. The damage information was divided again by the total area of buildings to obtain the unit relationships.

Residential growth projections involved an analysis of the area to determine what types of units have been built recently and what are likely to be built in the future. A further consideration was the interpretation of the National Flood Insurance Act which states that no residential structure can be built within the 100 year flood plain. It further states that the first habitable floor of new construction must be above the 100-year flood limits.

Several new apartment complexes have been built along the main stem and in Zone 6B (lower Pocasset River reach) with the basement level at the 100 year elevation. This appears to be the trend in certain portions of the available vacant residential and for the main stem zones. It will be assumed that the only residential land growth susceptible to significant damage within the flood plain will be limited to multi-unit apartment complexes similar to ones already built in the area.

In order to arrive at the unit-stage damage curve two apartment complexes were analyzed. The elevation of the first floor was determined by inspecting the stage-damage relationship. The two apartment complexes were then merged together for structural losses, contents and miscellaneous items such as non-physical losses. The latter item was most important as the instant water reaches above the floor of the basement or slab grade apartments, the entire heating and cooling plants along with the power transformers would sustain damage. It is then customary for the local building inspectors to revoke vacancy permits. Thus the entire complex, even with only one foot of water above the floors would be closed down. The duration of the closing is dependent upon the depth of flooding and the ease with which replacement parts can be obtained. Though this type of flood which would cause damage to these new apartment complexes

would exceed a hundred year event, many would sustain heavy damage to their power and heating plants in less frequent events. Replacement of these items has been estimated at a minimum of four weeks. Thus, for this category, even with only one foot of water the entire complex would be vacated for a minimum 4-week period. The typical complex consists of a basement or grade floor with three floors and eight units per floor.

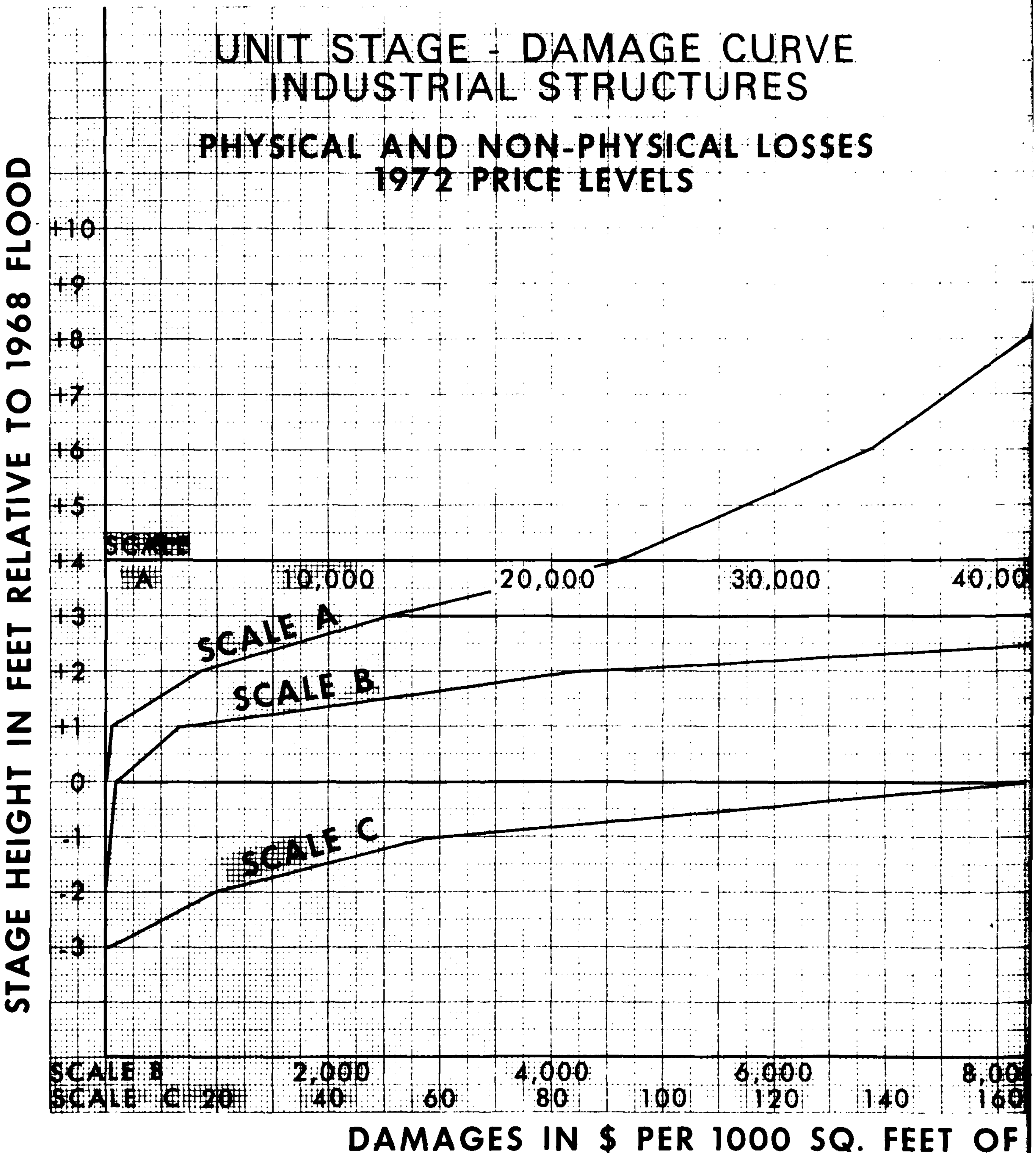
A further analysis was undertaken to determine what percent of a particularly zoned area would be actual structure. From similar type areas within the watershed, the average acre had the following percent buildup: commercial -27.5 percent; industrial -30 percent; residential -20 percent. For residential growth each acre of land had one 8-unit per floor for four floors per building relationship

It was then necessary to determine where the growth could occur and how much acreage would be developed for each of the three major land use categories. Table 1-12 in Appendix 1 represents the available land within the flood plain. It is significant to note that 53 acres of commercial land are available for growth, of which 24 are located in the floodway. As grading of the floodway for non-structural type usage such as parking lots is permitted, this full amount of land can be utilized with careful planning. Utilizing the growth rate calculated for this category, and dividing the available land by the growth rate, it is evident that without rezoning or reclassification of existing land, the available commercial land will be saturated with growth within 10 years from the date of analysis. From the land use analysis, it was determined that 75 percent of the projected commercial growth would be located in Zone 4 and the remainder in Zone 8.

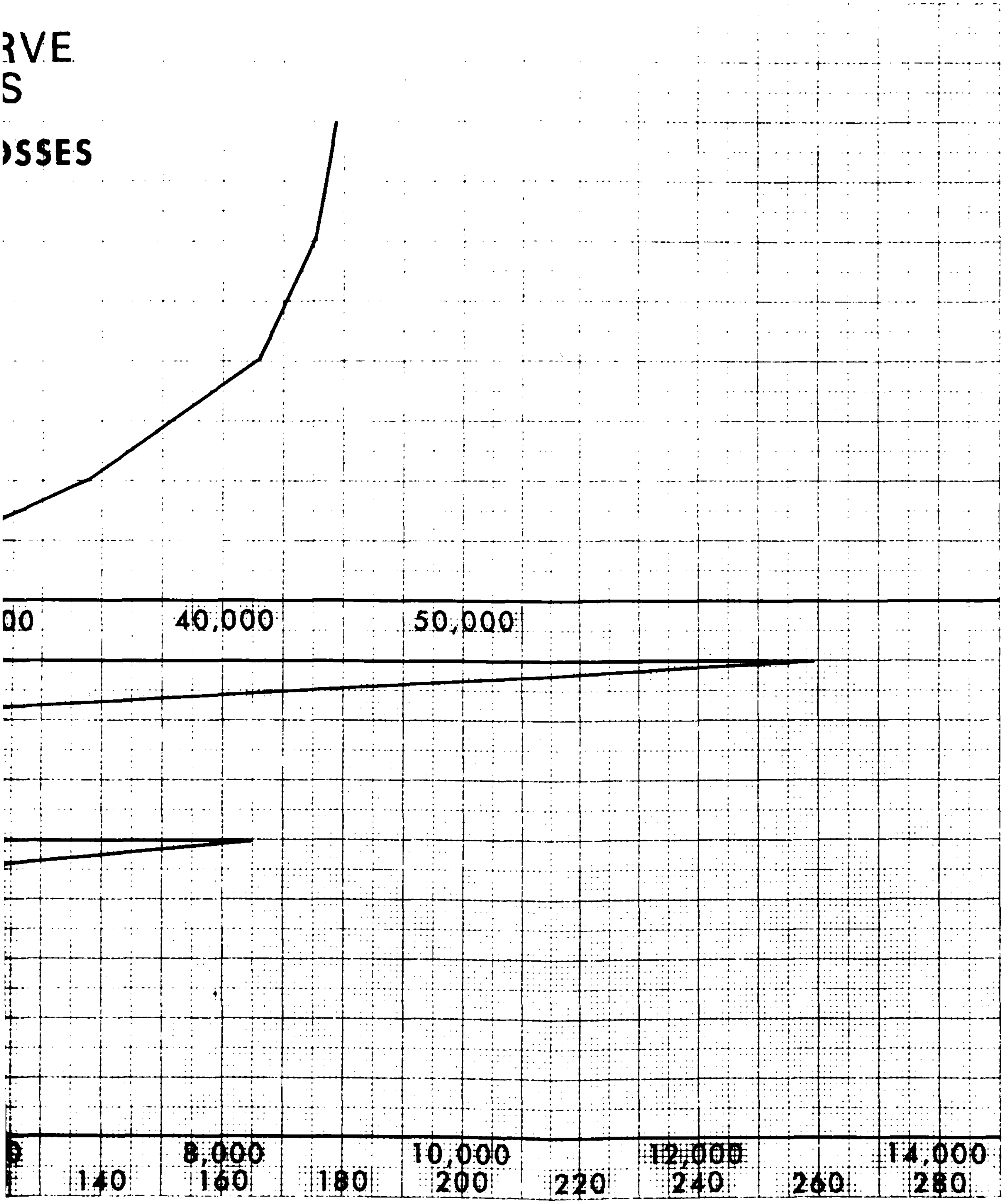
As sufficient land is available for both industrial and residential growth, saturation will not occur in the 1972-1990 growth period. Industrial growth, which will consume a total of only 39 acres of vacant land, was estimated to occur at the following percentages for the specified zone:

Zone 4	23%
Zone 5	33%
Zone 6	22%
Zone 8	22%

Residential growth was assumed to take place at a rate of 4.4 acres per year. Since residential land is at a premium, it is likely that only multi-family housing will be built and it is assumed that this type of housing (apartment complexes) would be only in Zone 4. Therefore, future residential growth was estimated only for this zone.



UNIT STAGE - DAMAGE CURVE
INDUSTRIAL STRUCTURES
PHYSICAL AND NON-PHYSICAL LOSSES
1972 PRICE LEVELS
STAGE HEIGHT IN FEET RELATIVE TO 1968 FLOOD
+10
+9
+8
+7
+6
+5
+4
+3
+2
+1
0
-1
-2
-3
SCALE A
10,000
20,000
30,000
40,00
SCALE A
SCALE B
SCALE C
SCALE B
2,000
4,000
6,000
8,00
SCALE C 20
40
60
80
100
120
140
160
DAMAGES IN $ PER 1000 SQ. FEET OF



SQ. FEET OF INDUSTRIAL STRUCTURE PLATE 7-6

Table 7-5 summarizes the total losses, benefits to the selected plan and residual losses from all 1972 to 1990 growth. Plate 7-7 shows a sample determination that was applied or industrial growth per acre for Zone 5.

FUTURE GROWTH OVER PROJECT LIFE (1990 - 2090)

This phase of growth activities will occur after the selected plan is operational. Growth will continue to occur at the pre-project growth rate of 3 acres per year for industrial zoned land. Growth will not be determined for residential use as existing multi-family zoned land is rather limited. Commercial vacant land is non-existent. Rezoning of vacant industrial land or single family residential land will not be assumed, although this practice has occurred within the study area. At the base year for project implementation, 1990 approximately 550 acres of industrial land should be vacant within the standard project flood confines. Significant vacant land is available in Zone 5, with lesser amounts in Zones 4 and 6. Little vacant land is available within the Cranston portions of Zones 7 and 8.

Benefits were estimated, after project implementation, for industrial growth in Zone 8 only. This is due to the fact that the Warwick local protection provides protection up to the standard project flood after implementation. Several of the existing firms in the Warwick Industrial Park (Warwick Avenue area) are now prohibited from enlarging their facilities because of existing constraint on expansion within the fifty year flood plain.

Because of the durability of locating within the Warwick Industrial Park (sewered area, adjacent to good connecting highway system, availability of public water supply and public transportation) new growth will continue in this area until the existing vacant land becomes saturated. In the period prior to project implementation (1972 - 1990), 12 acres of growth occurred within the Warwick Industrial Park. Growth during this period for industrial concerns averaged 3.0 acres per year but was spread among Zones 4, 5, 6 & 8. For the above mentioned reasons all growth after project completion will occur in Zone 8 (3.0 acres per year) until available vacant land is saturated. Approximately 50 prime acres of vacant industrial land were available at the base year. Twelve acres were developed during the pre-project growth period and it is assumed that roughly 25% of the land will be left vacant or used for road and sewer systems. At a growth rate of 3 acres per year saturation will occur in approximately nine years, (1999). Base elevations were then determined utilizing an average elevation of the existing vacant land and adding one foot to account for regrading and raising of the first floor

TABLE 7-5

1972 TO 1990 FUTURE GROWTH
BEFORE PROJECT COMPLETION
JUNE 1978 PRICE LEVEL

Type and Location	Total Annual Damages	Benefits to Big River Reservoir	Residual Losses	Benefits to Warwick LLP*	Final Residual Losses
INDUSTRIAL					
Zone 4	57,720	23,190	34,530	-	34,530
Zone 5	98,890	34,770	64,120	-	64,120
Zone 6	64,550	25,380	39,170	-	39,170
Zone 8	62,310	14,490	47,820	34,390	13,430
COMMERCIAL					
Zone 4	96,800	42,530	54,260	-	54,260
Zone 8	26,110	7,650	18,460	12,910	5,550
RESIDENTIAL					
Zone 4	138,060	53,560	94,490	-	94,490
TOTAL	544,440	210,570	342,850	47,300	295,550
Updated to Average 1979 Price Level	597,500	221,300	376,200	51,600	290,800

TABLE 7-6
Summary of Average Annual Benefits
for the Selected Plan
June 1978 Price Level - 6-5/8% Interest Rate

Type of Benefit	Big River Reservoir	Warwick Local Protection	Summation
Basic Flood Control	$514,560	$307,170	[illegible]
1972 to 1990 Growth	$201,750	$ 47,300	$249,050
1990 to 2090 Growth	$320,280	$565,750	$886,030
Location	--	$ 20,750	$ 20,750
Total Benefits	$1,036,590[1]	$940,970	$1,952,100
Total Annual Charges	$452,000[2]	$865,000	$1,317,000
Benefit to Cost Ratio	2.29	1.09	1.48

[1] As the recommended plan does not consider the Warwick Avenue Local Protection, the 1990 to 2090 growth benefits have not been included. Thus, the total flood control benefits for the Big River Reservoir Project are equal to $716,310. Update to September 1978, the benefits are approximately $725,000. Updated to average 1979 price levels, the benefits are 782,200.

[2] For detailed costs, see separate feasiblity report on Big River Reservoir.

structure. A new dummy unit stage damage curve was then prepared for this elevation. Damages were then evaluated in the absence of a flood control plan. Residual losses were then determined under modified conditions. Future industrial losses are shown below. The Warwick local protection works is taken as a second added in the system with Big River. The reservoir reduced floor stages at the protected areas and the system of walls and dikes at the Warwick Industrial Park offered complete protection up to the standard project flood. All residual losses up to the .15 percent annual chance of occurrence becomes a benefit to the local protection project.

FUTURE INDUSTRIAL LOSSES

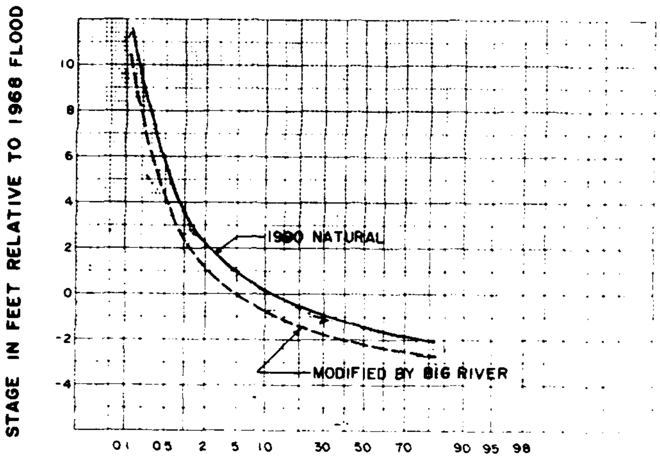
1990 - 2090

1978 Price Level; 6-5/8% Interest Rate

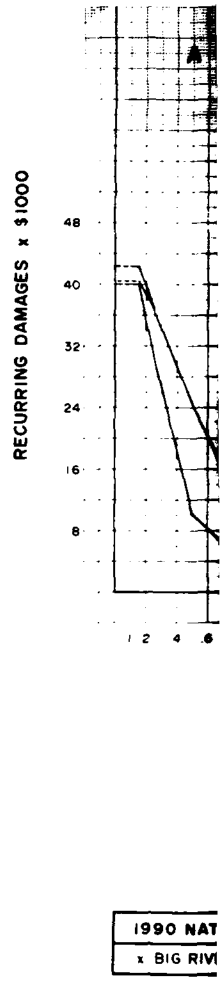
Location	Total Annual Damages	Benefits to Big River Reservoir	Residual Losses	Benefits to Warwick LPP	Final Residual Loss
Zone 8	$918,530	$320,280	$598,250	$565,750	$32,500
TOTAL	$918,530	$320,280	$598,250	$565,750	$32,500

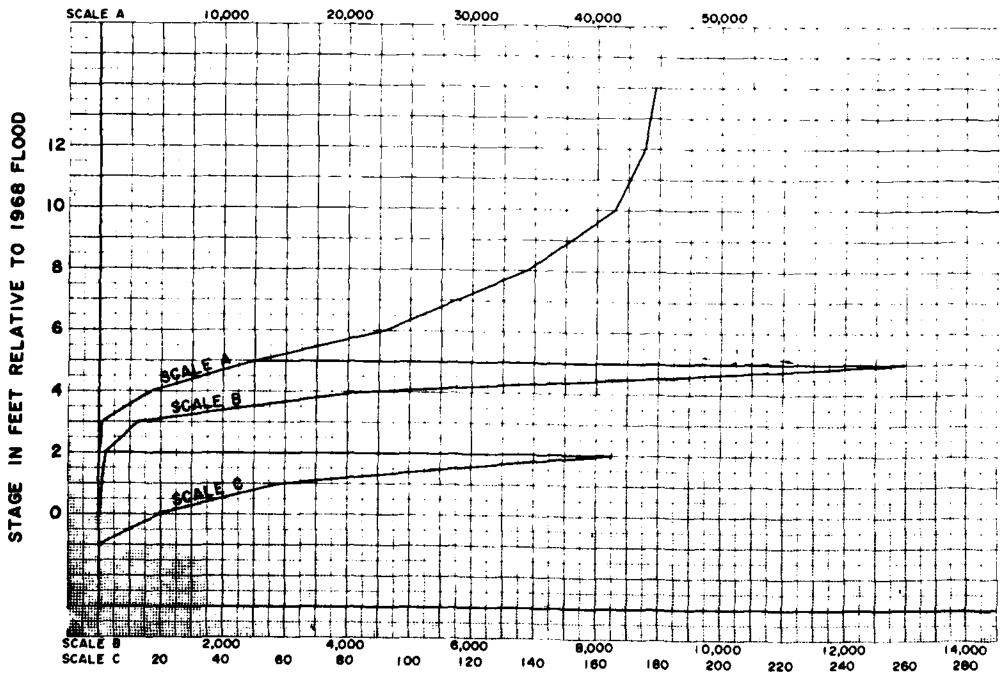
LOCATION BENEFITS

The ability of the project to make protected flood plain land available to new activities that would use the flood plain only after implementation of the selected plan results in location benefits. The value of this benefit is determined by employing two different techniques in accordance with ER 1105-2-351: (1) the change in the market value of land in the flood plain and (2) net income differences. Method (1) was selected for final calculations as it is the most quantifiable and factually supported method at the field level. Location benefits were taken only for the area protected by the Warwick Local Protection Works (Zone 8, Warwick) based on the high degree of safety against flooding provided. Big River Reservoir will have the effect of lowering flood stages one to two feet along the main stem thus changing flood plain limits, however, the consequence of urbanization could somewhat offset this favorable development. For this reason location benefits were not estimated for Zones 4 through 7. With the Warwick LPP in place and operational it was estimated by real estate brokers in the area and NED real estate personnel that the value of vacant industrial land would

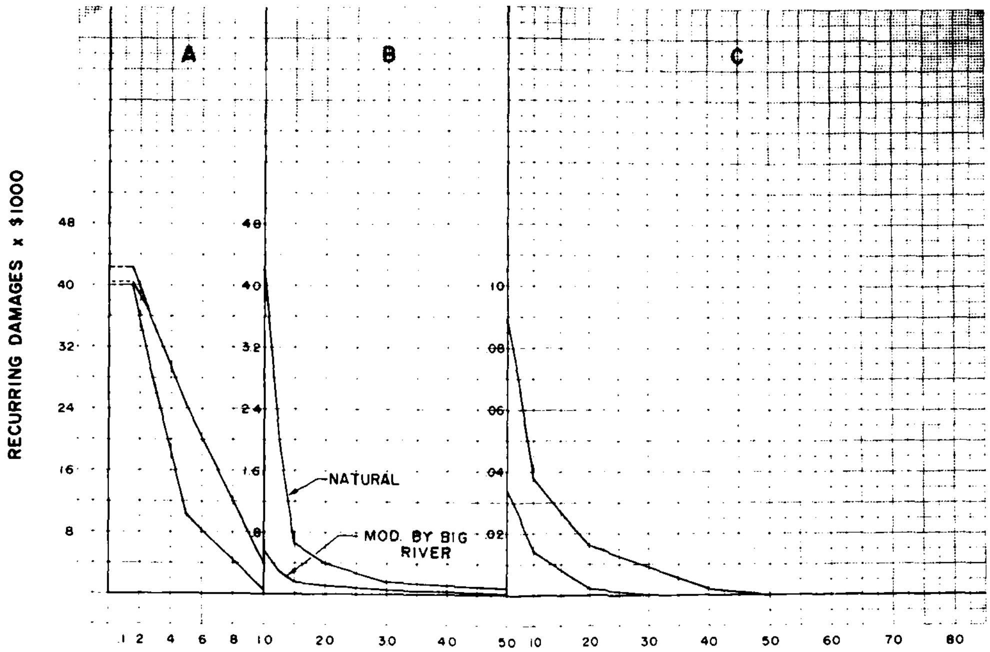


PERCENT CHANCE OF OCCURRENCE ANNUALLY
STAGE - FREQUENCY CURVE
NATURAL CONDITIONS
(INDEX STATION - RIVER SECTION 340+00)





DAMAGES IN $ PER 1000 SQ. FEET OF INDUSTRIAL STRUCTURE
STAGE - DAMAGE CURVE
1972 PRICE LEVEL
1972 STUDY; UPDATED 1978



PERCENT CHANCE OF OCCURRENCE PER SINGLE YEAR

DAMAGE-FREQUENCY CURVE
1972 PRICE LEVEL
1972 STUDY, UPDATED 1978
1970 HYDROLOGIC CONDITIONS

	RANGE A 1 sq. in. = $ 32			RANGE B 1 sq. in. = $8			RANGE C 1 sq. in. = $. 2			AVERAGE ANNUAL	
	AREA	LOSS	BEN	AREA	LOSS	BEN.	AREA	LOSS	BEN.	LOSSES	BENEFITS
1990 NAT	7.71	247		2.37	19		3.26	7		273	
x BIG RIVER	5.33	171	76	.51	4	15	1.05	2	5	177	96

ALL VALUES PER 1000 SQ. FEET OF INDUSTRIAL BUILDING

1972 - 1990

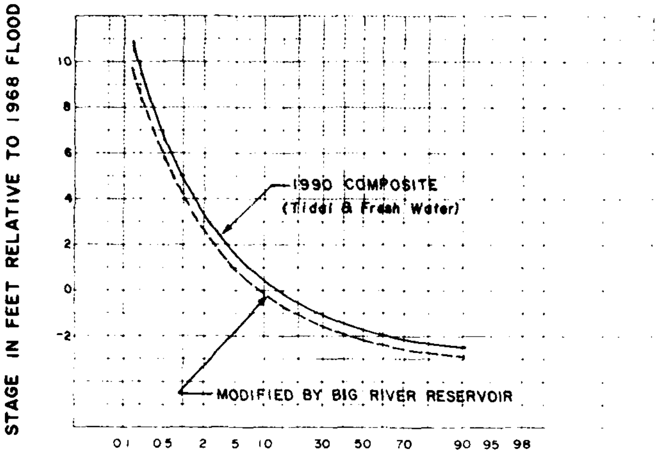
WITHOUT THE PROJECT CONDITIONS

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND
DAMAGE-FREQUENCY-STAGE RELATIONSHIPS
INDUSTRIAL GROWTH-ZONE # 5

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 7-7

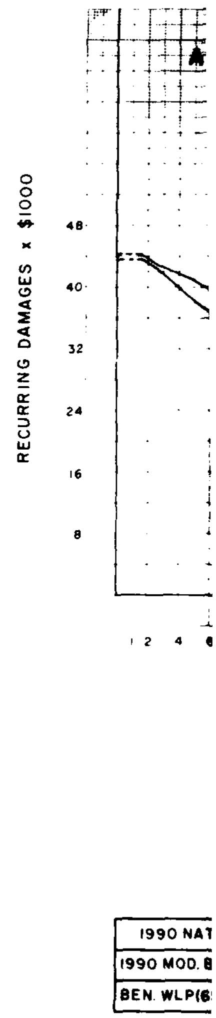


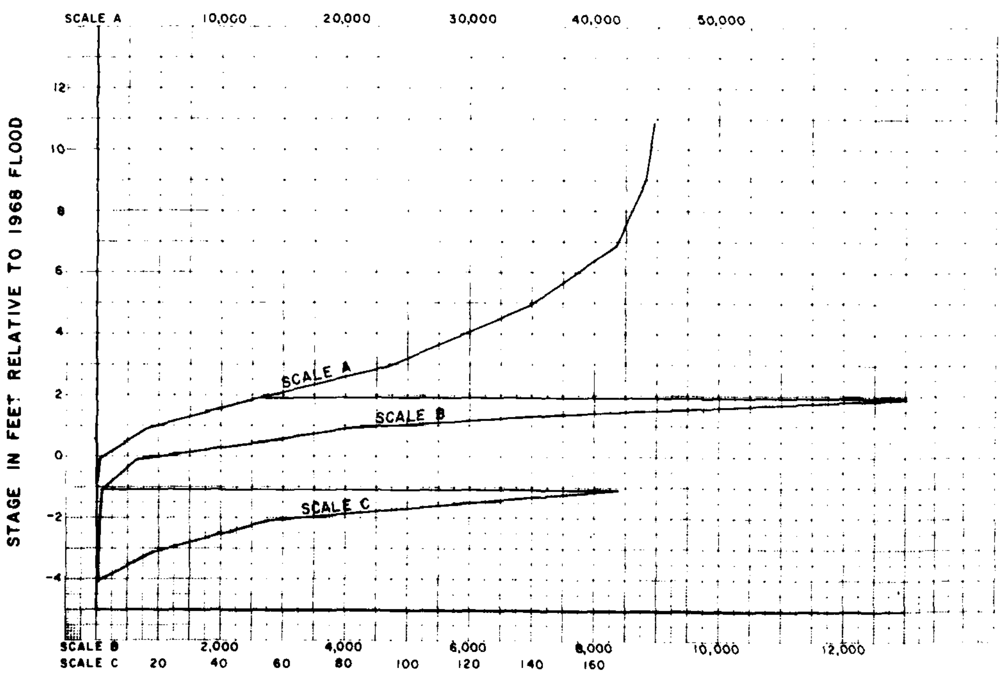
PERCENT CHANCE OF OCCURRENCE ANNUALLY

STAGE-FREQUENCY CURVE

NATURAL CONDITIONS

(INDEX STATION - WARWICK AVENUE)



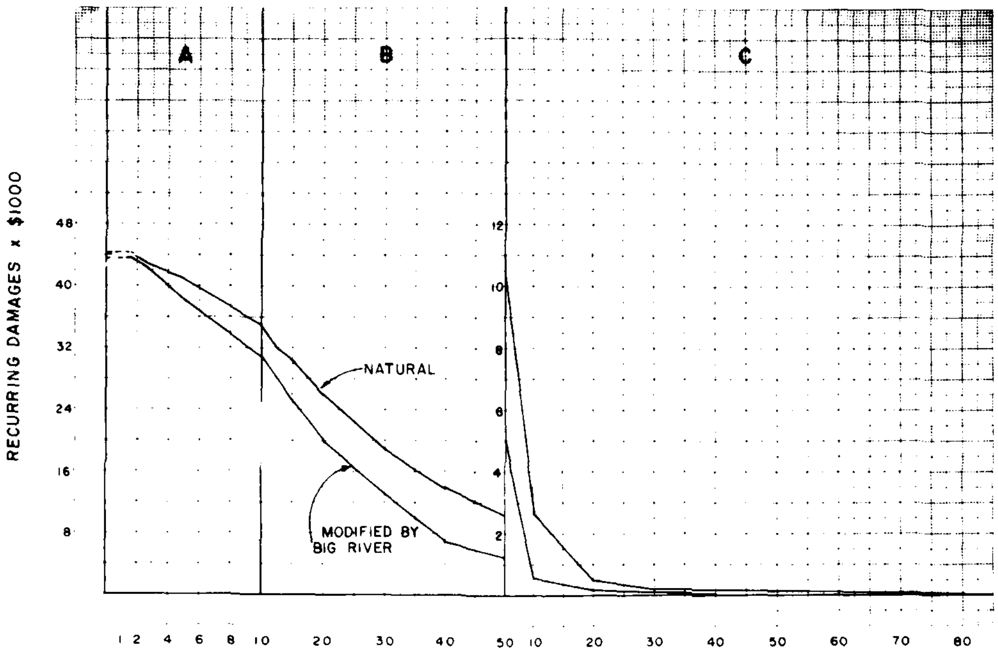


DAMAGES IN $ PER 1000 SQ. FEET OF INDUSTRIAL STRUCTURE

STAGE-DAMAGE CURVE

1972 PRICE LEVEL

1972 STUDY; UPDATED 1978



PERCENT CHANCE OF OCCURRENCE PER SINGLE YEAR

DAMAGE - FREQUENCY CURVE
1972 PRICE LEVEL
1972 STUDY, UPDATED 1978
1990 HYDROLOGIC CONDITIONS

	RANGE A 1 sq. in. = $32			RANGE B 1 sq. in. = $80			RANGE C 1 sq. in. = 200			AVERAGE ANNUAL	
	AREA	LOSS	BEN	AREA	LOSS	BEN	AREA	LOSS	BEN.	LOSSES	BENEFITS
1990 NAT.	12.64	404.5		10.16	812.8		3.25	650		1867.3	
1990 MOD. B.R.	11.95	382.5	22	7.89	631.2	181.6	1.01	202	448	1215.7	651.6
BEN. WLP(650)	2.05	65.6	316.8	0	0	631.2	0	0	202	65.6	1,150

ALL VALUES PER 1000 SQ FEET OF INDUSTRIAL BUILDING

INDUSTRIAL GROWTH

AFTER PROJECT IMPLEMENTATION

WATER RESOURCES MANAGEMENT REPORT

PAWTUXET RIVER BASIN
RHODE ISLAND

DAMAGE-FREQUENCY-STAGE RELATIONSHIPS

1990 TO 1999 GROWTH-ZONE #8

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

increase at least \$.25 per square foot. This is based upon real estate estimates of value of comparable flood - prone versus flood-free land. After the Warwick LPP is operational 27 vacant acres would be available for development. This increase in value is calculated as follows:

27 acres X 43,560 s.f/acre X .25 = \$294,030
\$294,030 X .09 (the Federal rate of return) = \$26,463

Since the vacant acreage will be developed gradually up to saturation in nine years the benefit must be discounted based on 9 years of growth, 100 year project life and an interest rate of 6-5/8%.

The location benefit now equals \$20,750.

Benefit Analysis for Non-Structural Flood Control Plan for the Norwood (Belmont) Area of Warwick Rhode Island

Benefits estimated in the following sections are those which accrue through the implementation of a non-structural flood control plan involving the 60 highly floodprone residential properties located on the Norwood peninsula. Essentially the plan involves outright purchase of various properties and evacuation, through demolition, of them from the flood plain. The Norwood area has a history of flooding with the most notable events having occurred in the years 1968, 1978 and 1979. A structural plan consisting of walls and dikes has been formulated to protect the Norwood area, however, the plan is not economically justified.

Benefits were evaluated in strict adherence to ER 1105-2-353, "Evaluation of Non-structural Measures" under the following categories:

I. Net Income Earned by Activities Occupying the Floodplain with the Project

II. Reduction of Externalized Flood Damages

  A. Reduction of Flood Emergency Costs
  B. Reduction of Insurable Flood Damages
  C. Reduction of Flood Damages to Utility, Transportation and Communication Systems

III. Other Public Savings

IV. Locational Advantage Accruing to Off-Floodplain Properties Adjacent to the Open Space

I. Net Income Earned by Activities Occupying the Floodplain with the Project.

The "with project" condition would consist of the purchase and demolition of the properties in the Norwood area. Subsequent to the demolition, the area would be graded and seeded resulting in an open green space. At that time the Federal Government would still own the land and the future ownership, e.g. sale to the city of Warwick, is not known. It is also not known to what use the vacant land would be put. Certain cost sharing arrangements could be undertaken between Warwick and certain Federal agencies to construct recreational facilities, however, future courses of action are unformulated at this time. For the above reasons, no estimates of the type of new activities that would occupy the floodplain, demand for the new activities and dollar value per use have been made. Consequently, benefits or net income earned by new activities have not been estimated for this category.

II. Reduction of Externalized Flood Damages.

Externalized flood damages are actually costs which are not borne by without-project floodplain occupants. These externalized costs of floodplain occupancy are typically borne by taxpayers or firms providing services to floodplain activities. Therefore, elimination of the externalized costs result in a benefit which accrues to the nonstructural plan. The benefits are evaluated under the following three categories:

A. Reduction of Flood Emergency Costs.

Flood emergency costs consist of costs that accrue directly as a result of floodplain inundation. In the absence of a flood potential for the area, these costs wold be eliminated and would result in a benefit. Example of emergency costs are: (1) overtime pay to police, fire, public works civil defense and other rescue related personnel, (2) shelter costs involved in housing, feeding and treating floodplain victims who were evacuated from their homes and (3) equipment costs for rescue vehicles, fire engines, pumps, and public works vehicles involved in the evacuation and flood-fighting effort. Since flooding occurs on a non-regular basis and in differing intensity, data on emergency costs is somewhat difficult to ascertain if not collected by specific event by one central agency. In the city of Warwick, the data had to be collected after the fact by one agency, therefore, an additional source was also employed. This source was damage survey in other cities after specific events. The percentage of emergency costs of total damages was estimated and applied to total damages in the Norwood area for a specific event. Total emergency costs were estimated at approximately 16 percent of total losses at each stage event, and then annualized. This is equal to $48,366.

B. Reduction of Insurable Flood Damages.

Since the Norwood area is in Warwick, it is eligible for flood insurance under the National Flood Insurance Program. The premium for flood insurance coverage is subsidized by the U.S. Government in high risk areas. The subsidized portion of flood insurance costs is a benefit nationally, since its elimination is a savings to all U.S. taxpayers; tax funded subsidies support flood insurance payments. The following method was used to compute the benefit for flood insurance subsidy savings. Coverage for structure and contents for each property was estimated separately. For each structure in the Norwood area the elevation of the first floor and the elevation of the 100-year flood was ascertained. The height of the first floor above or below the river elevation was computed from actual field surveys. Using the appropriate tables in the Federal Flood Insurance Manual, the premium paid per $100 of coverage was found

based on the type of structure and the height above or below the river elevation. The actual policy holders permium, $.25 per $100 of coverage was subtracted from the total premium to obtain the subsidized portion. All property owners were assumed to purchase insurance up to the assessed value of their properties. Computations were made for each structure and the total subsidy to coverage to structures was $45,762. A similar method was used to establish the subsidized coverage for contents. Based on previous studies it was assumed contents are valued at 50 percent of structural value and it was assumed that homeowners will insure up to that amount. A $10,000 ceiling was placed on contents coverage as this is the limit for the first layer or subsidized portion of flood insurance coverage for residential contents. Again computations were performed for each property and the subsidized portion of premium payments for contents coverage was $23,588. The "with-project" condition would result in a total annual saving (benefit) of $69,350. A final adjustment to the benefit is to allow for deductibles on both the structural and contents coverage. Both categories were reduced by 2 percent to account for this and the resulting benefit is $67,970.

C. Reduction of Flood Damages to Utility, Transportation and Communication Systems

Recurring damages under this category were estimated by damage appraisers from this office for various stages of flooding in the Norwood area. Damages stemmed from weakened utility poles and resulting line damage, cracked and heaved asphalt roads and damage to bottle gas set ups. Combining stage damage data with hydrologic stage frequency date results in annual losses of 30,600 which would become a benefit under the "with-project" condition.

III. Other Public Savings.

Another externalized cost which relates to the flood insurance program is the cost of its administration. Elimination of this administrative cost is a savings to the nation. The benefit is based upon the average cost per policy including agent commission, servicing and claims adjusting costs. The cost for agent commissions is 15 percent of the payable premium and for this study the savings (benefits) amounts to $11,172. At this time, servicing and claims adjustment costs per policy could not be determined from agency sources, therefore, the $11,172 will stand as the benefit.

IV. Locational Advantage Accruing to Off-Floodplain Properties Adjacent to the Open Space.

The positive externality or adjacent lands reflects the amenity of living near park land or open space and is measured as the projected increase in market value of property adjacent to the encumbered floodplain. This benefit was not evaluated based on the unique geographical location and neighborhood makeup bordering Norwood. The fact that the area is a peninsula bordered by the river and a main street with an industrial/commercial/residential mix makes evaluation difficult. In addition the benefit must be documented by empirical evidence not available at present.

Summary of Benefits Accruing to Non-Structural Flood Control Plan (Evacuation) for the Norwood Area

Benefit	$ Value
Reduction of Flood Emergency Costs	$ 48,366
Reduction of Insurable Flood Damages	67,970
Reduction of Flood Damages to Utility, Transportation and Communications Systems	30,690
Other Public Savings	[illegible]
Total	$158,1[illegible]

*for 50 homes

Benefits for different number of homes are based on average benefit per house multiplied by the total number of homes to be acquired.

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